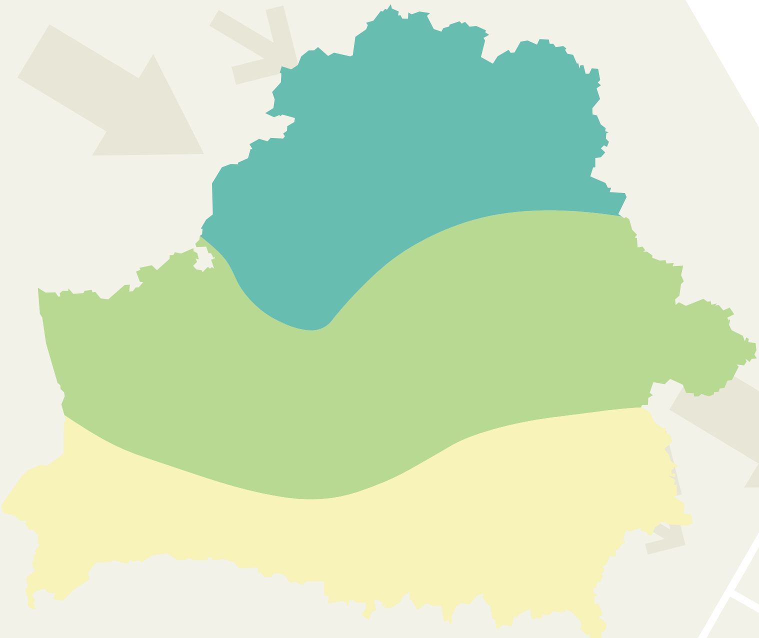
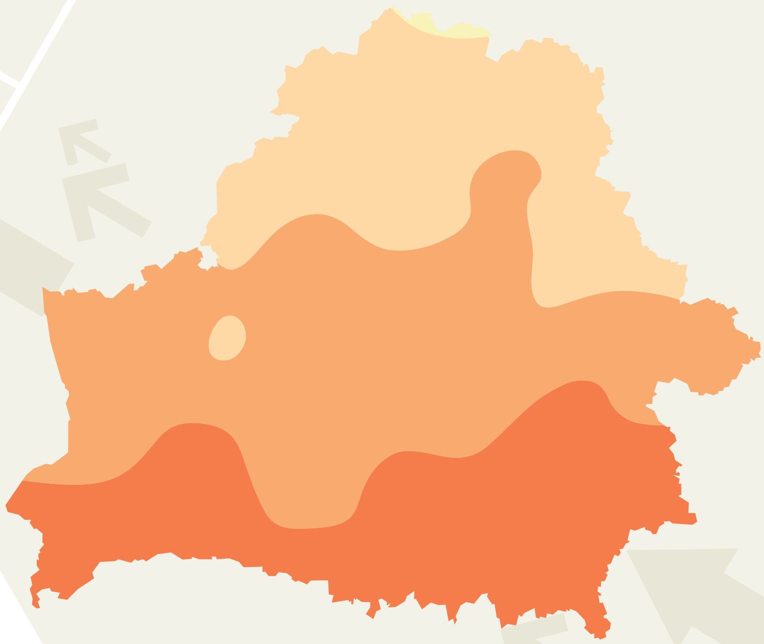


ClimaEast

STRATEGY FOR ADAPTATION OF AGRICULTURE TO CLIMATE CHANGE IN THE REPUBLIC OF BELARUS

Preliminary version

Minsk 2017



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with broad use of findings of activities in the framework of the Expert Facility under the Clima East project“ Supporting Climate Change Mitigation and Adaptation in Russia and ENP East Countries”:

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- Agroclimatic Zoning of the Territory of Belarus with Account of Climate Change (contract CEEF2016-071-BL);
- Assessment of Agricultural Vulnerability to Climate Change in the Republic of Belarus and Assessment of Potential Damage in the Short- and Long-Term Perspective (contract CEEF2016-072-BL);
- Review of Practical Experience and Development of Recommendations for Agricultural Sector Adaptation to Climate Change (as exemplified by plants protection) with Account of EU Experience (contract CEEF2016-073-BL).

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CONTENTS

1 INTRODUCTION

As assessed by the Intergovernmental Panel on Climate Change under the United Nations Framework Convention on Climate Change, climate warming in Europe is more rapid than the global average. At the end of the 20th and the beginning of the 21st century Belarus witnessed the longest warming period during the entire period of instrumental air temperature observations over the past one hundred and thirty years. The peculiarity of the current warming is not only in its unprecedented duration, but also in the higher air temperature, which has on average exceeded the climatic norm by 1.2 ° C over the last twenty-five years (Melnik, 2006).

The consequences of climate change have a significant impact on agriculture, which largely depends on the weather and climate conditions, and, accordingly, on food security of the country. No matter how successful the efforts to reduce greenhouse gas emissions on a global scale are, and whichever is the actual implementation of scenarios of global climate change, due to the delayed consequences of greenhouse gas emissions, the impact thereof in the coming decades will increase. Therefore, we have no choice but to adopt adaptation measures to mitigate the inevitable climatic impacts and their economic, environmental and social costs. The use of coherent and flexible approaches to adaptation and the introduction of appropriate measures will ultimately be cheaper than the cost of untimely or inefficient adaptation.

Sound land use is a priority for sustainable development and ensuring environmental security in the Republic of Belarus, and maintaining the sustainability of agriculture is one of the conditions for the stability of the country. Among the most important policy documents aimed at minimizing the impact of climate change on the economic sectors, including agriculture, special attention should be paid to the State Program of Measures to Mitigate the Effects of Climate Change for 2013–2020. The program contains a number of areas for adapting agriculture, including:

- development of technologies for cultivation of drought-resistant and heat-loving crops;
- adaptation of species composition of fodder crops to changing climatic conditions and related optimization of the structure of sown areas;
- improvement of observations of climate change, reduction of climate impact and adaptation to changing climate;
- minimizing the risk of reducing agricultural production, including a reduction in the productivity of farm animals, crop yields and gross crop yields.

However, given the importance of the agricultural sector for the economy, social sphere and the future of Belarus, it is necessary to create special framework documents for implementation of systematic state policy in this area. Comprehensive adaptation measures elaborated and implemented in the agricultural practice will be particularly helpful in dealing with issues that the industry and the country are facing today.

Development of this S Strategy for Adaptation of Agriculture to Climate Change in the Republic of Belarus is the first step on this path.

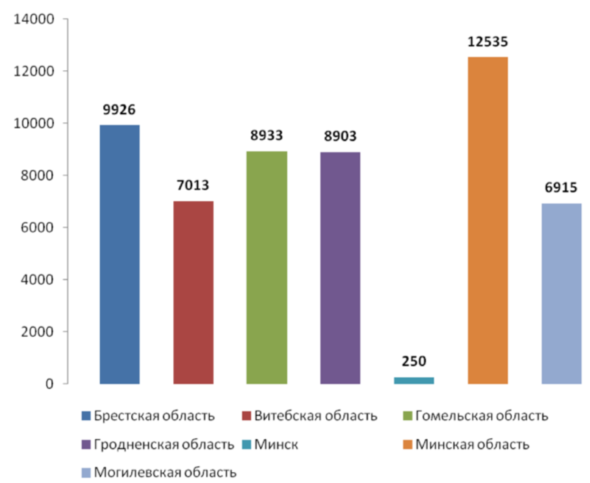
2 BELARUSIAN AGRICULTURE AND ITS DEPENDENCE ON CLIMATE CHANGE

2.1 General Characteristics of Branches of Agriculture in the Republic of Belarus [1]

Agriculture is an important branch of economy of the Republic of Belarus, which, together with forestry and hunting, provides about 8% of the country's GDP, 17.1% of investments in fixed assets and about 10% of employment. The total land area in agricultural turnover is almost 9 million hectares, or more than 40% of the country's territory. One inhabitant of Belarus accounts for 0.9 hectares of agricultural land, including 0.6 hectares of arable land. The agricultural sector employs more than 330,000 people or 8% of the total number of employed in the country's economy. 23% of the country's population lives in rural areas[2].

The main products of Belarusian agriculture are milk, cattle meat and poultry, grain, potatoes, vegetables, sugar beet and flax for industrial processing. It is produced by agricultural organizations, peasant (private) farms, and also by the population. Large-scale production has always been and still remains a priority direction of development of the Belarus' agro-industrial complex. Agricultural organizations, including farms, produce about 78% of the industry's output; the population accounts for 22%. Agricultural organizations account for about 87% of agricultural land, private farms hold 1.7%, the population holds about 10%, while other land users have 1.3%.

Leaving behind the peasant (private) farms in terms of production volume, agricultural organizations are inferior to them in terms of efficiency. This concerns a significant amount of support thereof by the state in different forms with a virtually equal level of yield per hectare (36.7 against 36). According to the latest indicator for the production of potatoes and vegetables, farmers leave behind themselves both the economy of the population and agricultural organizations.



In regional terms, agriculture is most important for the Minsk region, where the added value of its production was 1.6% of GDP in 2014. Next come the Brest and Gomel regions (1.3% and 1.2% respectively).

Picture 2.3. Gross added value generated by agriculture, mln BYR in 2014 current prices (Kozyra at al., 2017, based on National Statistical Committee data)

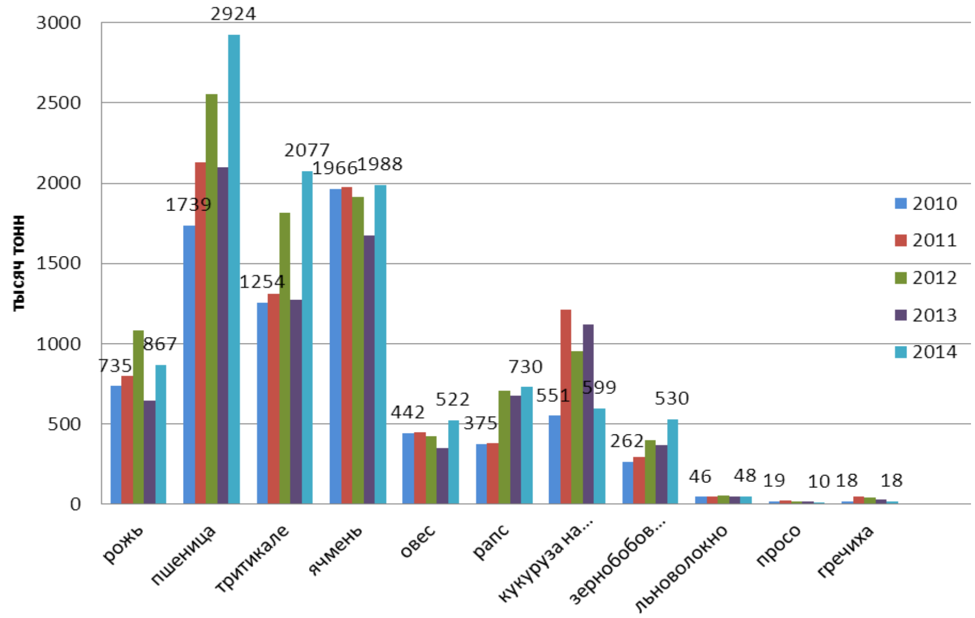
Бретская область	Brest oblast	Минск	Minsk
Гродненская область	Grodno oblast	Гомельская область	Gomel oblast
Могилёвская область	Mogilev oblast	Минская область	Minsk oblast
Витебская область	Vitebsk oblast		

Crop Production

Belarusian crop production specializes in growing traditional crops for middle latitudes with cereals prevailing (barley, wheat and triticale mostly), as well as potatoes, fodder and technical crops.

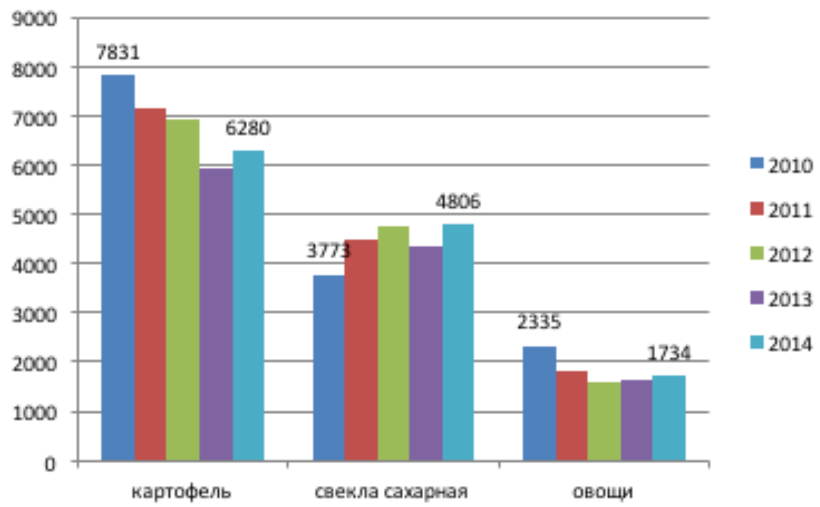
[1] The section is prepared based on the following materials: Kozeltsev, 2016
[2] Data from the Ministry of Agriculture and Food of the Republic of Belarus (www.mshp.gov.by)

Agricultural production of cereals is based on large- and medium-sized agricultural production enterprises (that account for approximately 95% of the overall production). Potato accounts for approximately 85% of crops planted by the population, while vegetables contribute 67% (National Statistical Committee, 2015).



Тысяч тонн	Thousand tons	Ячмень	Barley	Зернобобовые	Legumes
Рожь	Rye	Овес	Oat	Льноволокна	Flax fiber
Пшеница	Wheat	Рапс	Rapeseed	Просо	Millet
Тритикале	Triticale	Кукуруза на семена	Corn left for seeds	Гречиха	Buckwheat

Picture 2.1.1 Dynamics of gross crop yields for core crops in farms of all categories (National Statistical Committee, 2015)



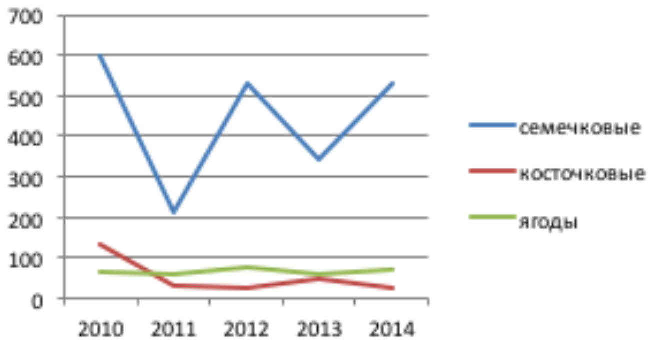
Катрофель	Potatoes	Свекла сахарная	Sugar beet	Овощи	Vegetables

Picture 2.1.2 Dynamics of gross yields of potatoes, beets and other vegetables in farms of all categories (National Statistical Committee, 2015)

In recent years, there has been a trend towards reduced potato production due to reduction of the area of potato fields. In the private sector potatoes are used mainly for food, seeds and livestock, and grown in agricultural organizations – for domestic and foreign markets as a commodity. Commodity potato farming is characterized by high economic efficiency.

Gardening

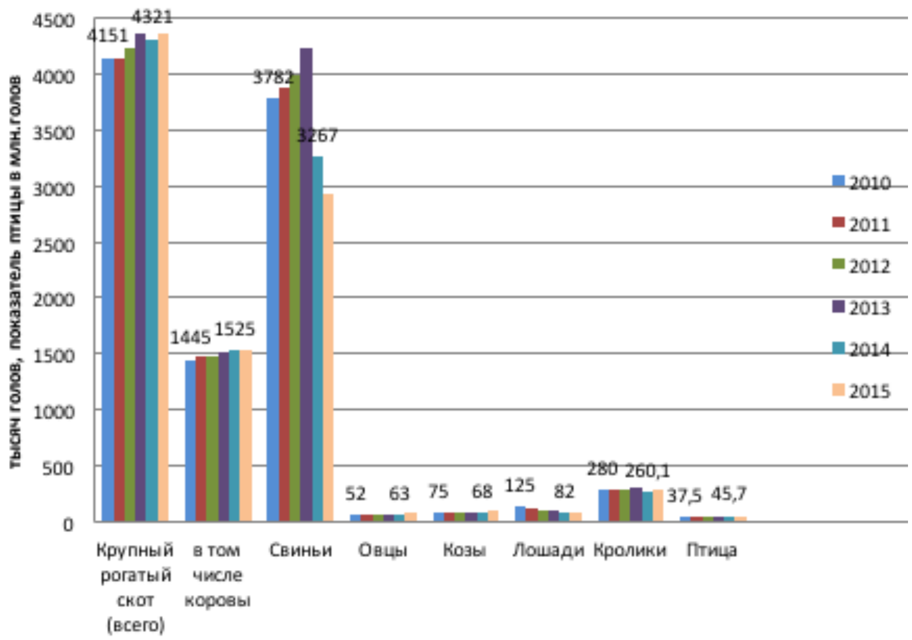
The country's farms of all categories have 104.5 thousand hectares of fruit and berry plantations, including 43.8 thousand hectares, or 42% of the total area, in agricultural organizations and peasant (private) farms. Pomegranate crops (apple, pear, plum) occupy 88% in the total volume of fruit and berry plantations of the country's public sector (43.8 thousand hectares), stone fruits - 1% (cherry, plum), berry crops - 11% of the total area.



Семечковые	Pomaceous fruit	Косточковые	Stone fruit	Ягоды	Berries

Picture 2.1.4 Dynamics of gross yield of crops and berries in farms of all categories (National Statistical Committee, 2015)

Livestock Farming



Тысяч голов, показатель птицы в млн.голов	Thousands of heads, the number of birds in millions of headlines	Крупный рогатый скот (всего)	Cattle (total)	козы	Goats
		В том числе коровы	Including cows	лошади	Horses
		Свиньи	Pigs	кролики	Rabbits
		овцы	sheep	птица	Poultry

Picture 2.1.3 Dynamics of livestock numbers in farms of all categories (as at the start of the year) (National Statistical Committee, 2015)

Livestock farming produces more than 50% of the agricultural output of the Republic of Belarus and forms the basis of the export potential of the Belarusian agro-industrial complex. Traditionally, Belarus specializes in the production of milk, breeding cattle, pigs and poultry[3]. The share of cattle breeding accounts for more than half of the value of gross livestock production. The main part of the livestock population is concentrated in agricultural organizations - 96% (including cows - 90%). Dairy cattle breeding is one of the leading branches of livestock farming, and one third of material and cash resources spent is used here. More than 55% of the harvested volume of milk is supplied to the foreign market in the form of dairy products. Poultry farming is one of the country's most intensive branches with 29 kilograms of poultry meat and 417 eggs produced per capita annually.

Fish Farming

Fishing breeding activities in the Republic of Belarus are represented by two main directions: breeding and growing fish in artificial conditions, and fishing in fisheries. In recent years, Belarusians have consumed 160-180 thousand tons of fish products, i.e. 16 - 18 kilograms per capita annually, which corresponds to the world average of 16.7 kilograms. The country's aquaculture includes pond fish farming, fish farming in cages, pools and closed water supply systems.

In the near future, until 2020, the main strategy for the development of fishery activities in the country is to increase the efficiency of fish growing and enhance competitiveness of fish products using existing and newly created facilities to provide the population with fresh fish of traditional (carp, white carp, silver carp) and "valuable" species (trout, sturgeon, etc.). In pond fish farming, the main focus is to increase economic efficiency, ensuring the preservation of achieved productivity while minimizing the overheads that form the cost of production. In industrial fish farming the emphasis is on completing the construction of fish hatchery complexes and reaching their designed capacity, which would allow to achieve the planned production volumes. The questions of determining the sound volume of production that allows to sell fish products without significant losses and increased costs in the process of storage and sale, as well as rational filling of the domestic market remain open.

Pasture fish farming based on natural and artificial reservoirs adapted for its tasks, which allows to obtain high-quality fish products at significantly lower costs than pond fisheries remains an insufficiently used resource.

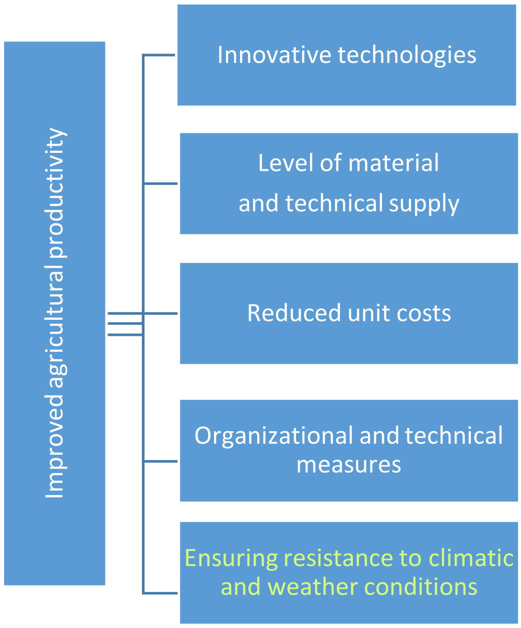
Bee Keeping

Beekeeping is an ancient occupation of the population of Belarus with thousand-year traditions. At present, individual small-scale production predominates in the beekeeping of the country, in which 82.4% of the total number of beekeeping families is located.

[3] Data from the Ministry of Agriculture and Food of the Republic of Belarus (www.mshp.gov.by)

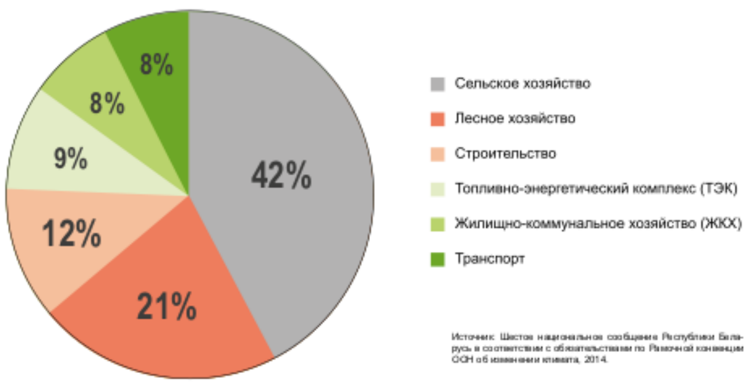
2.2 Dependence of Agriculture on Climate Change[4]

Climate change has both positive and negative consequences from the point of view of agricultural output. Yield fluctuations caused by weather conditions are objective reality and occur despite general improvements in farming standards.



Picture 2.2.1 Conditions for improved agricultural productivity (Kozeltsev, 2016)

The most important condition for improving agricultural productivity is achieving its sustainability in relation to weather and climate change. It is estimated that the industry accounts for more than 40% of damage from adverse weather and climate conditions in the Belarusian economy.

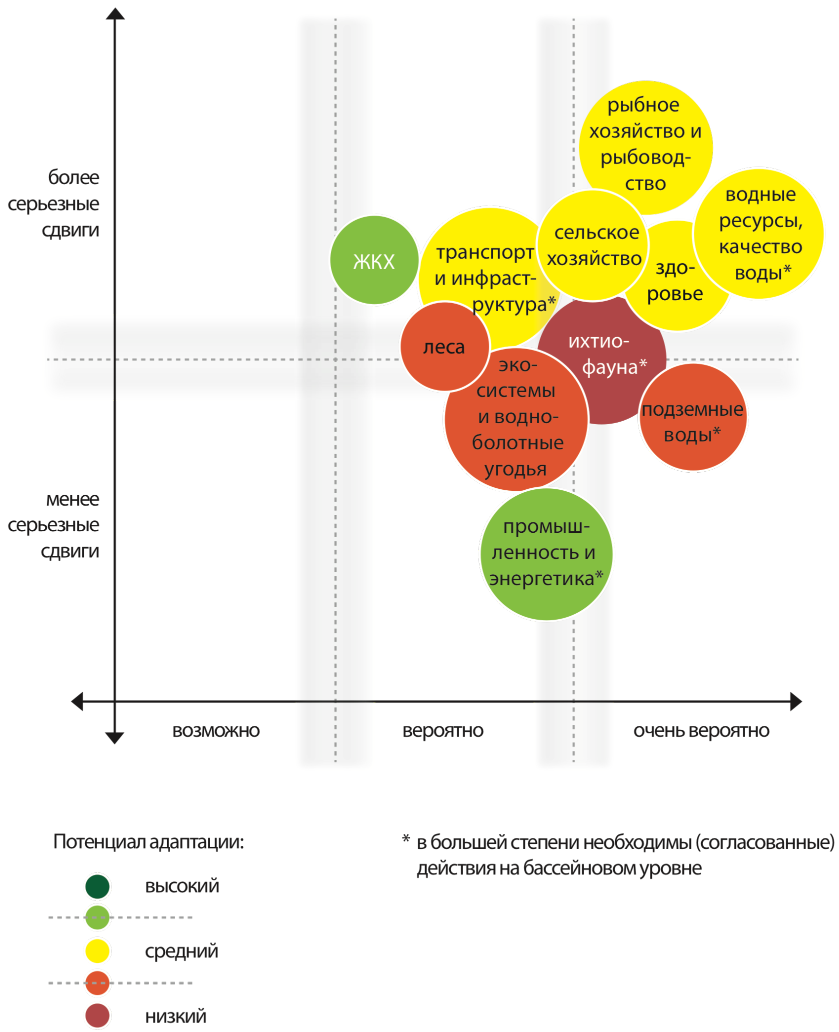


Сельское хозяйство	Agriculture	Топливно-энергетический комплекс (ТЭК)	Fuel and Energy Complex
Лесное хозяйство	Forestry		
Строительство	Construction	Жилищно-коммунальное хозяйство (ЖКХ)	Housing and Utilities
Транспорт	Transport		

[4] The section is prepared based on: Melnik, 2006, Kozeltsev, 2016, Yakimovich et al. 2017

Picture 2.2.2 Assessed distribution of damage from adverse hydrometeorological events, breakdown for industrial sectors in Belarus (Zoï Environment Network and UNDP, 2015, based on the Sixth National Communication under UN FCCC)

A wide range of specialists and organizations involved in consultations regarding consequences of climate change in the Neman river basin included agriculture among the most vulnerable industries (UNECE and UNDP in Belarus, 2015).



Picture 2.2.3 Probable consequences of climate change in the Neman river basin (UNECE and UNDP in Belarus, 2015)

Более серьезные сдвиги	More significant shifts	Промышленность и энергетика	Industry and energy	Потенциал адаптации	Potential for adaptation
Менее серьезные сдвиги	Less significant shifts	Экосистемы и водно-болотные угодья	Ecosystems and water and swamp areas	Высокий	High
ЖКХ	Utilities	Ихтиофауна	Ichtiofauna	Средний	Medium
Леса	Forests	Рыбное хозяйство и рыбоводство	Fish breeding and fishery	низкий	Low
Сельское хозяйство	Agriculture	Транспорт и инфраструктура	Transport and infrastructure	В большей степени необходимы (согласованные) действия на бассейновом уровне	Cooperative action at the basin level is required (to a greater extent)
Здоровье	Health	Возможно	Possible		
Подземные воды	Underground waters	Вероятно	Likely		
Водные ресурсы и качество воды	Water resources and water quality	Очень вероятно	Very likely		

Belarus' agriculture is in the zone of "risky farming", and climatic fluctuations in conditions lead to a change in its gross output by 15-20%, meat and milk production - by 10-15%, costs for the production of cattle and pigs - by 5 - 15%. Depending on the weather conditions, gross grain harvest can vary from 5.5 to 9.5 million tons, and in some years it is about 60% of the country's minimum food security level.

Specialists distinguish the following weather phenomena that are key for agriculture: rainless and rain periods, high and low temperatures, droughts, frosts, thaws, ice crusts, heavy rains, thunderstorms, tornados and squalls, "dual-core winters" (Loginov, 2010). Some of these phenomena can be predicted with great lead time and probability. Some of them arise spontaneously and can cause significant damage.

The greatest damage to agricultural production is caused by drought. In highly arid years, the yield of cereals and leguminous plants can drop by 10-20%, and in the years of exceptionally severe drought, which is observed every 100 years, yields may decrease by 30-40%.

The state of wintering crops is influenced by uneven snow cover in the fields and sudden temperature fluctuations that cause the crops to freeze or outflow. For example, winter crops rot in winters with a stable (no less than 30-40 days) snow cover 30 cm high and over, when soil freezes to a depth of 50 cm, and when at the depth of the tillering node the temperature is close to 0 ° C. In such conditions, plants intensively spend carbohydrates on breathing, and by the end of winter they are depleted and die.

Increased heat supply within a certain range contributes to expansion and improvement of the structure of crop production, but with a significant increase in the average annual temperature, agriculture in the southern and eastern regions of the country will face a persistent issue of insufficient water availability for crops, drying of the plow layer and other drought manifestations. The cost of producing cereals during large-scale dry phenomena increases by 15-20% compared to the favorable years, which leads to a decrease in labor productivity by approximately the same amount.

Table 2.2.1 Positive and negative effects of climate change on crop production
(based on Melnik, 2006; Yakimovich et al., 2017 with addenda)

POSITIVE	NEGATIVE
Earlier spring seasons and increased duration of vegetation period	Increased likelihood of extreme and unfavorable hydrometeorological conditions
Increased heat supply for agricultural crops	Increased maximum air temperatures
Advancement of the growing area of heat loving crops to the north	More frequent and intense droughts, especially in the south
Possibility for expansion of sowing areas of grain, millet, soybean, spring rape, etc.	More frequent and long-lasting periods of extreme heat (heat waves)
Improved conditions for growing stubble and shrubby crops	Overall increase in fire risks in forests and peatlands adjacent to fields
Improved conditions for overwintering of agricultural crops and sown perennial grasses	Possibility of freezing during the flowering period
Increase efficiency of measures aimed at	More often and more durable winter thaws

improving soil fertility	(possibly damage to winter crops)
Later occurrence of autumn frosts (which makes harvesting cereals, beetroot and potatoes easier)	Deficiency of water during the growing period, lower level of ground waters and deterioration of soil moistening conditions
Lower frequency of winters with temperatures dangerous for winter crops	Deterioration of growth conditions for flax, and of the second cut of grasses due to increased dryness of the second half of summer
Earlier end of spring frosts and increased duration of the frost-free period	Loss in winter crop yields due to reduced precipitation in September
Increased duration of the postharvest period	Increase in the costs due to switching to irrigated vegetable farming
Possibility of introduction of yielded moderately late varieties (hybrids) of cereals and vegetables	The growth of extreme precipitation, soil erosion and plant damage due to more intense precipitation
The shift in the timing of sowing spring crops to an earlier time	Occurrence of new pests and diseases of agricultural crops, improved conditions for overwintering of pests and development of weeds
Improved conditions and reduced time for harvesting	Lower plant tempering, increased likelihood of their damage from wetting, temperature fluctuations and diseases
Earlier onset of the first cut	Significant increase in financial and labor costs for seeds, fertilizers, reseeding and crop insurance

Livestock production is also affected by climate change. High summer temperatures can increase the mortality of animals as a result of heat stress and other phenomena. To cope with temperature fluctuations, animals need to regulate metabolism, which can lead to a decline in production of meat, milk and eggs. In practice, the productivity of livestock (specific production of meat and milk products) will increase in warm winter seasons and decrease in warm summer seasons.

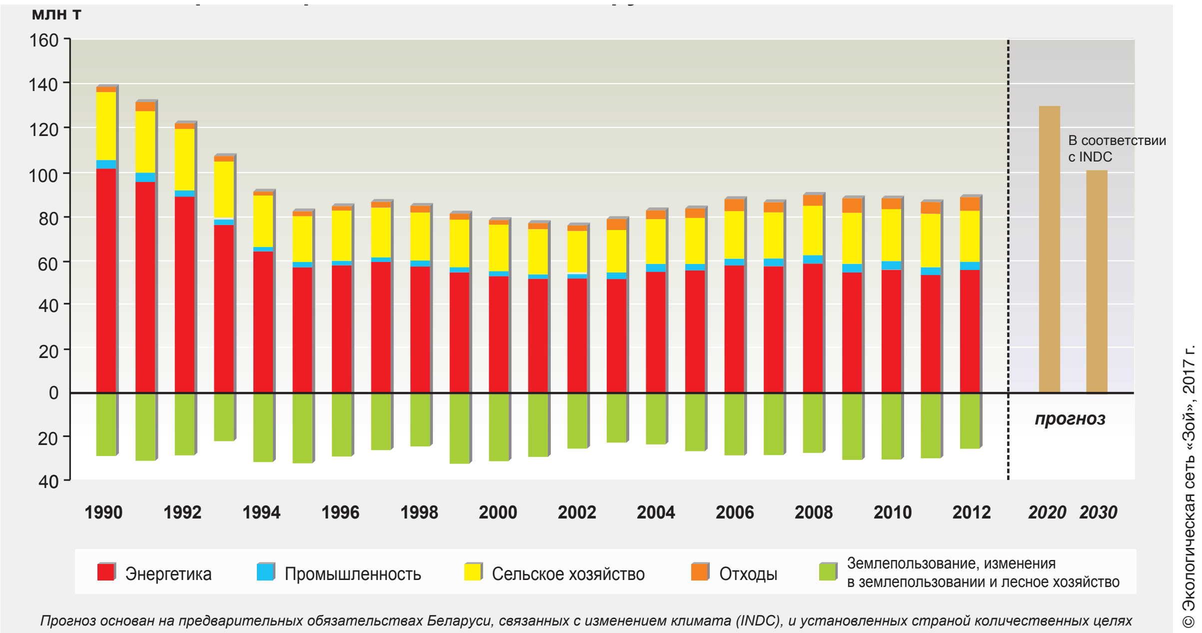
Table 2.2.2 **Positive and negative effects of climate change on livestock and fish farming** (based on Melnik, 2006; Yakimovich et al., 2017 with addenda)

POSITIVE	NEGATIVE
Increased pasture period Decreased costs of heating premises in winter Increased feed production	The danger of heat stress, a drop in productivity, increased demand for water Increased expenses for ventilation and electricity supply for premises Difficulty in grazing and producing fodder on wetlands along with increased rainfall Emergence of new infections, parasites and alien species Change in the temperature regime and deterioration of conditions in fishponds, lack of water for recharge Reduction of spawning grounds, changes in the composition of the ichthyofauna

The efficiency of fish farming is largely determined by the water and temperature regimes of the water bodies used, which are directly or indirectly related to climate change. Changes in environmental conditions (water temperature, dissolved oxygen, ice regime) lead to changes in fish productivity and species composition (which can simultaneously create opportunities for breeding new fish species). Changes in the ichthyofauna and a reduction in fish biodiversity are likely due to disappearance or reduction of spawning areas. Occurrence of alien invasive species can have a negative impact on fishing in the fishing grounds. Due to the reduction of runoff and lowering of surface water levels, as well as redistribution of water between the branches of the economy, a shortage of water resources for fishery enterprises can be expected.

In beekeeping, hot and dry weather will promote the increase of sugar content of nectar and cause a significant decrease in its production by plants, appearance of diseases and earlier occurrence thereof, as well as a decrease in the activity of bees. An increase in the frequency and duration of winter thaws can lead to a reduction in the population of bees, which in turn will lead to decreased pollination of agricultural plants.

At the same time, agriculture itself is one of the core sources of greenhouse gas emissions into the atmosphere. Even without taking into account land use, its changes and fuel consumption by agricultural transport, the industry is responsible for 20% of greenhouse gas emissions in Belarus. Therefore, a promising path of agricultural development must simultaneously increase the sustainability and productivity of the industry in the face of climate change and reduce its negative impact on the global climate system.

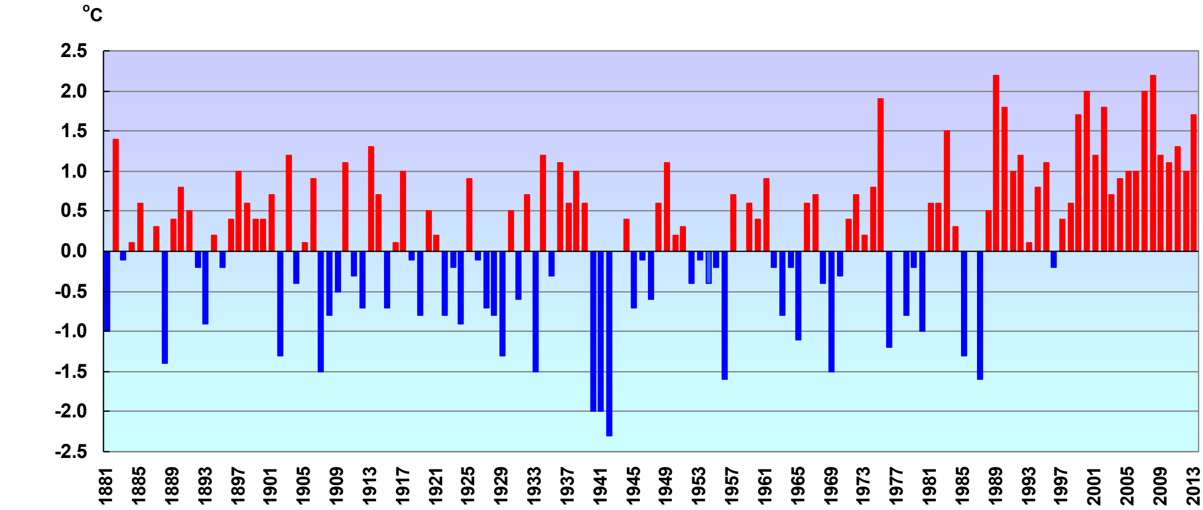


Млн т	Mln tons	Сельское хозяйство	Agriculture	Прогноз	Projections
Энергетика	Energy	Отходы	Waste	В соответствии с INDIC	In line with INDIC
Промышленность	Industry	Землепользование, изменения в землепользовании и лесное хозяйство	Land use, changes in land use and forestry	*Прогноз основан на предварительных обязательствах Беларуси, связанных с изменением климата (INDIC) и установленных страной количественных целях*	The projections are based on Belarus' obligations related to climate change (INDIC) and the quantitative goals set by the country

Picture 2.2.4 Greenhouse gas emissions in Belarus and projected changes
(Zoï Environment Network, 2017, based on the National Communication to UNFCCC)

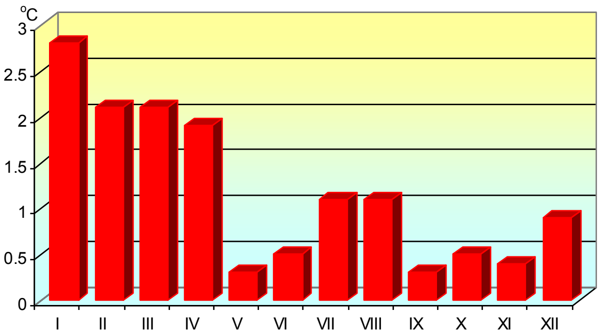
3 CLIMATE CHANGE AND ITS IMPACT ON BELARUSIAN AGRICULTURE

3.1 Historical Trends[5]

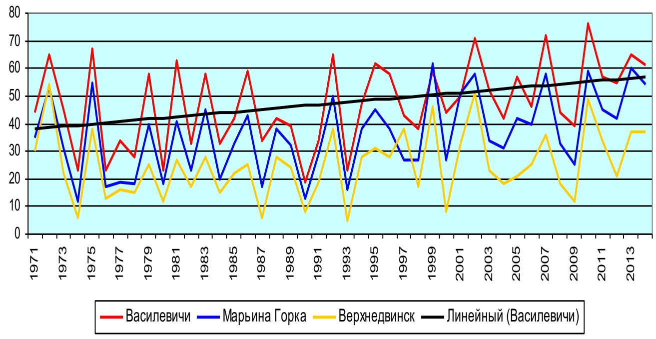


Picture 3.1.1 Variation of the average annual air temperature in Belarus from the climatic norm (Melnik, 2013, based on data from the Center of Hydrometeorology of the Republic of Belarus)

At the end of the 20th and in the early 21st century, Belarus experienced the longest warming period for the entire time of instrumental observations of air temperature over the past almost one hundred and thirty years. The peculiarity of the current warming is not only in its unprecedented duration, but also in a higher air temperature, which on average exceeded the climatic norm by 1.2 ° C. Of the twenty warmest years of the post-war period, since 1945, eighteen occurred in 1989 - 2013 years. The increase in air temperature occurred almost every month, most significantly - in winter and early spring.



Picture 3.1.2 Variation of the average monthly air temperature from long-term annual average for 1989 – 2013 (Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)



Василевичи	Vasilevichi	Верхнедвинск	Verkhnedvinsk
Марьина Горка	Mar'ina Gorka	Линейный (Василевичи)	Line (Vasilevichi)

Picture 3.1.3 The number of hot days (with maximum air temperature of +25°C and above) in 1971 – 2013 (Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)

[5] The section is prepared based on Melnik, 2013, Melnik et al., 2017, Yakimovich et al, 2017

Duration of the no-frost period tends to increase in Belarus. Recent studies by the Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring showed that, compared with 1951-1990, the frequency of years with spring and autumn frosts decreased in most stations (except for the Gomel oblast, where the frequency of spring frosts in May has increased in general). Over the past twenty-five years, the frequency of years with freezing in the second decade of May has increased at most meteorological stations in the country, and in the Gomel and Mogilev oblasts it is a universal trend. In autumn, during the warming period, the frequency of frost recurrence decreases in September - the third decade of October, which is a positive factor for agriculture.

Table 3.1.1 Changes in the main air frost indicators in the territory of Belarus in 1989-2013 compared to 1951-1990

(Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)

OBLAST	Difference in dates of frost occurrence		Extension of the no-frost period
	Last in spring	First in autumn	
Vitebsk	5	4	9
Grodno	7	3	10
Minsk	5	3	8
Mogilev	2	2	4
Brest	4	2	6
Gomel	2	1	3

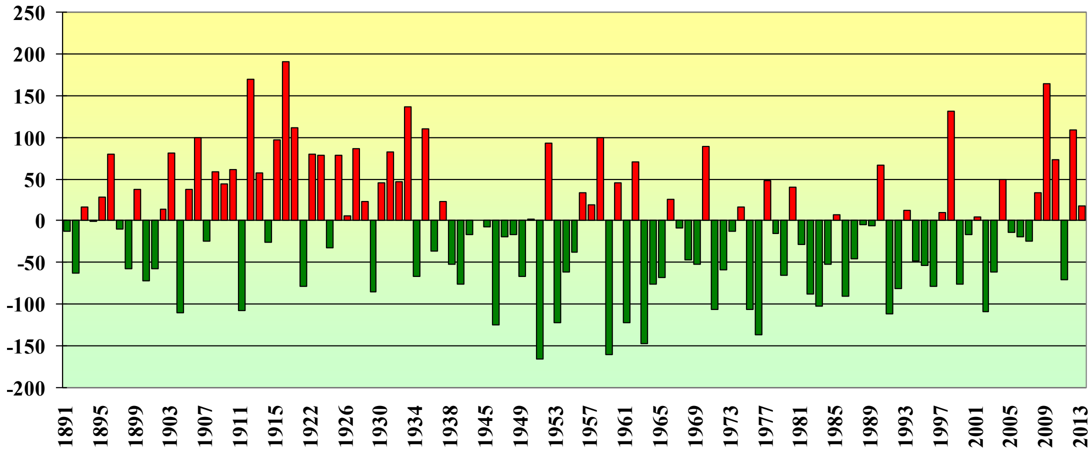
Increased temperature in the first spring months leads to an earlier descent of the snow cover and a transition of the air temperature through 0°C towards an increase. On average, during the period under review, this transition occurred 10 to 15 days earlier than the long-term annual average. The duration of the period with snow cover was reduced by 10 to 15 days, and the depth of freezing of the soil decreased by 6 to 10 centimeters. The dates of the beginning and the end of the transitions of the average daily air temperature and through other characteristic limits have changed, as well as the duration of the periods between these dates. So, the vegetation period begins 10 days earlier, and its duration increased by 12 days, respectively.

Table 3.1.2 Transition of the mean daily air temperature through characteristic landmarks

(Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)

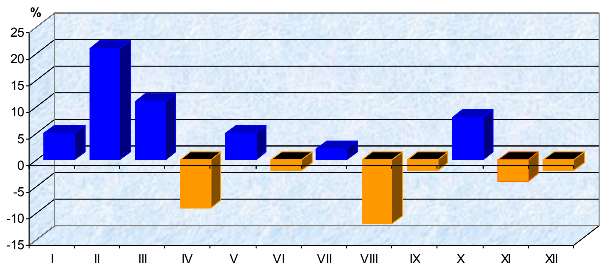
CLIMATIC NORM			TRANSITION IN 1989 – 2013		
Beginning	End	Duration	Beginning	End	Duration
Transition through 0°C					
25.03	19.11	239 days	16.03	23.11	251 days
Transition through 5°C					
13.04	23.10	193 days	5.04	28.10	205 days
Transition through 10°C					
2.05	25.09	146 days	27.04	28.09	153 days
Transition through 15°C					
31.05	30.08	91 days	30.05	2.09	95 days

During the last decades a 2-6% drop in precipitation has been discovered in most regions of Belarus (insignificant growth has been registered only in the Vitebsk region).

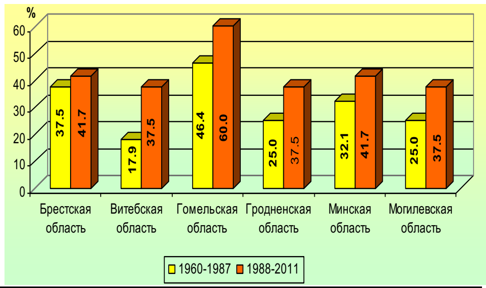


Picture 3.1.4 Variation of the annual precipitation (mm) from the climatic norm Отклонение (Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)

In warm weather, precipitation falls below the norm in April, June and, especially, in August. Somewhat more rainfall occurs in February, March and October.



Picture 3.1.5 Variation (%) of monthly precipitation in 1989 – 2013 from the climatic norm (Melnik, 2013 based on data from the Center of Hydrometeorology of the Republic of Belarus)

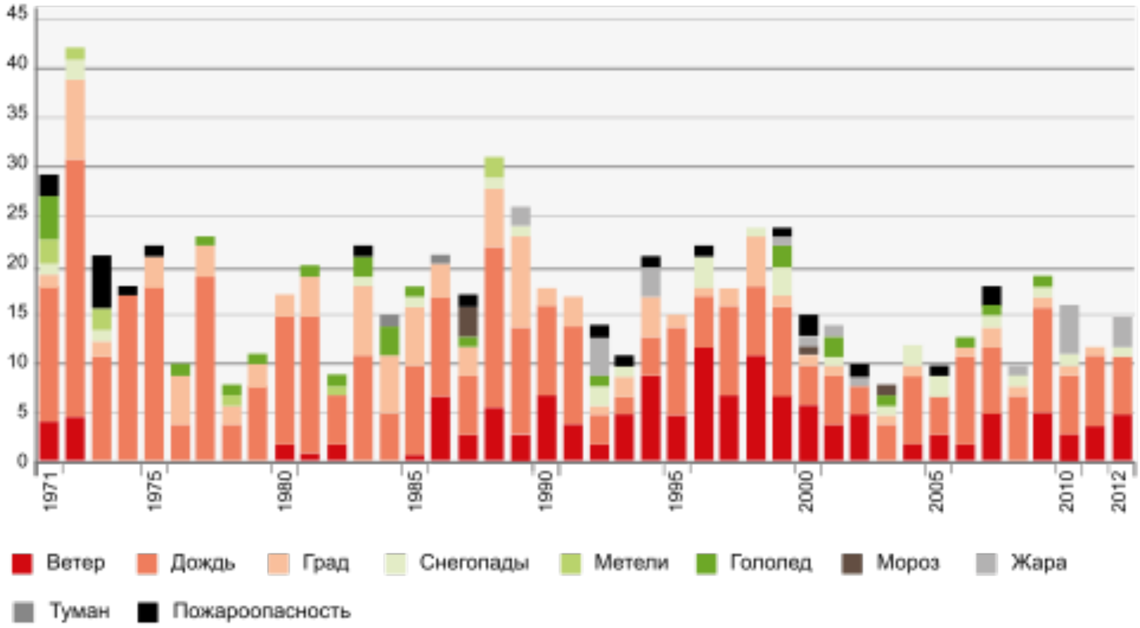


Брестская область	Brest oblast	Гродненская область	Grodno oblast
Витебская область	Vitebsk oblast	Минская область	Minsk oblast
Гомельская область	Gomel oblast	Могилевская область	Mogilev oblast

Picture 3.1.6 Recurrence of droughts before and after climate heating (Melnik, 2013, based on data from V.F.Loginov)

Increasingly, extreme weather events are occurring in Belarus, and the droughts of 2010 and 2015 and subsequent hot years confirm this trend. The number of droughts increased in all areas without exception, especially in the south of the country.

In addition to increased frequency of droughts and arid phenomena, the tendency to an increase in the frequency of extreme and unfavorable hydrometeorological conditions is manifested in the increase in the frequency, duration and intensity of periods of extreme heat ("heat waves"), a decrease in the number of days with low precipitation and precipitation intensity (leading to soil erosion and damage to agricultural plants).



Ветер	Wind	Град	Hail	Мороз	Freezing weather
Туман	Fog	Снегопады	Snowfall	Жара	Heat
Дождь	Rain	Метели	Snowstorms		
Пожароопасность	Fire danger	Гололёд	Ice-crusted ground		

Picture 3.1.7 Distribution of the number of dangerous climatic events for 1971 - 2012
(Zoï Environment Network and UNDP in Belarus, 2015, based on data from the Center of Hydrometeorology of the Republic of Belarus)

In terms of agriculture, the trend of warming in the winter period is ambiguous. Significant positive aspects include, above all, a longer growing period and increased heat supply that may create more favorable conditions for cultivation of a number of crops. The adverse effects are associated with the increase in frequency and duration of winter thaws and the associated increase in the probability of damage to winter crops resulting from waterlogging, damping-off, snow mold etc. Furthermore, in temperate latitudes winter crops need a period of low rates (vernalization) at the beginning of the winter period.

A sharp drop in air temperature to critical values in the absence of snow cover, which can lead to freezing and death of crops and causes a decrease in crop yields, also poses significant danger.

Due to prolongation of hot periods in the second half of the summer, conditions for formation of yield of medium and late varieties of potato, flax, cabbage, and second grass cut are deteriorating.

Acute water deficit in 2014 - 2015 led to a reduction in the fish feeding areas and a 30% increase in the vegetal invasion of fish ponds.

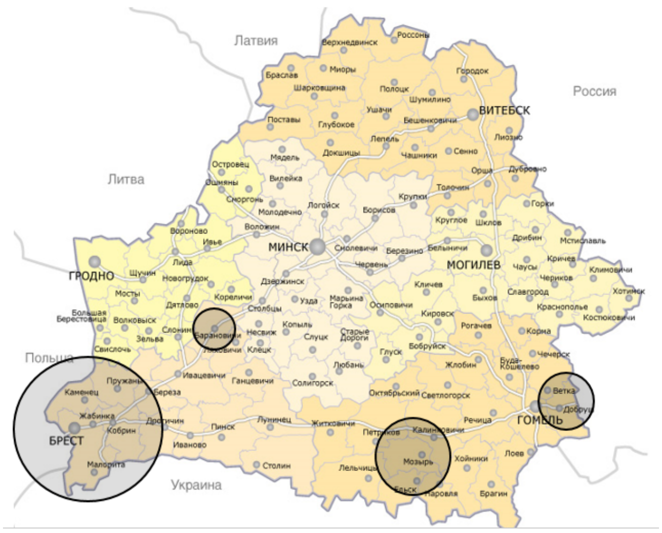
Changes in climatic conditions in the Republic of Belarus entailed certain changes in the phytosanitary situation, including planting cereals. Variation of the temperature and the amount of precipitation from the previously recorded ones contributed to a change in the harmfulness of pests that are usual for the country's territory and the appearance of new pests that previously did not pose a practical danger:

- Over the last ten years, winter wheat and triticale have been affected by epiphytotic diseases of snow mold (*Microdochium nivale* (Fr.) Samuels & I.C. Hallett) in the six growing seasons, with development of up to 85.2% and plant deaths up to 76.0%;

- The growth of soil fungi, which are causative agents of root rot of the *Fusarium Link.* genus and, in case of their domination inhibit the development of useful species of fungi and microflora, has spread;
- Stress resistance of field populations of toxin-forming fusarium fungi of cereals and corn has increased. In case the ear is infected, they can produce mycotoxins, which are the strongest carcinogens;
- Diseases of cereal crops, that had not been noted earlier, have appeared: for example, pyrenoforose (yellow spot), the causative agent of *Pyrenophora tritici-repentis* (Died.) Drechsler. The severity of the disease is expected to increase in the future;
- Due to the high temperature background in winter, leafs of the winter wheat and winter triticale suffer damage from the yellow rust (*Puccinia stiiformis* Westend.), and there is increased prevalence and extent of damage to crops by other types of rust: brown (*Puccinia recondita* Roberge ex Desm.), crown (*Puccinia coronifera*) and pygmy (*Puccinia hordei* G.H. Otth.);
- Intensive development of diseases was detected, the causative agents of which react positively to an increase in the sum of temperatures: dark brown patchiness (*Bipolaris sorokoniana* (Sacc.) Shoemaker), powdery mildew (*Blumeria graminis* (DC.) Speer), etc.

Warming has a great influence on promotion of heat-loving plant pests to the Republic of Belarus: for example, diabrotics (*Diabrotica virgifera virgifera* Le Conte). In 2016, the invasion of a new pest - a common bread beetle (*Zabrus tenebrioides* Goeze) was registered for the first time.

The harmfulness of pests is increasing: in 2013, 2015 and 2016 in many regions of the Brest and Gomel oblasts in agrocenoses of winter triticale, wheat, barley and rye there was an increase in the number and an increase in the severity of turnip moth (*Agrotis segetum* Schiff.), which was triggered by the increased temperature background in the autumn period.



Picture 3.1.8 The turnip moth habitat in the territory of Belarus in winter cereals in (Yakimovich et al., 2017, based on route reviews)

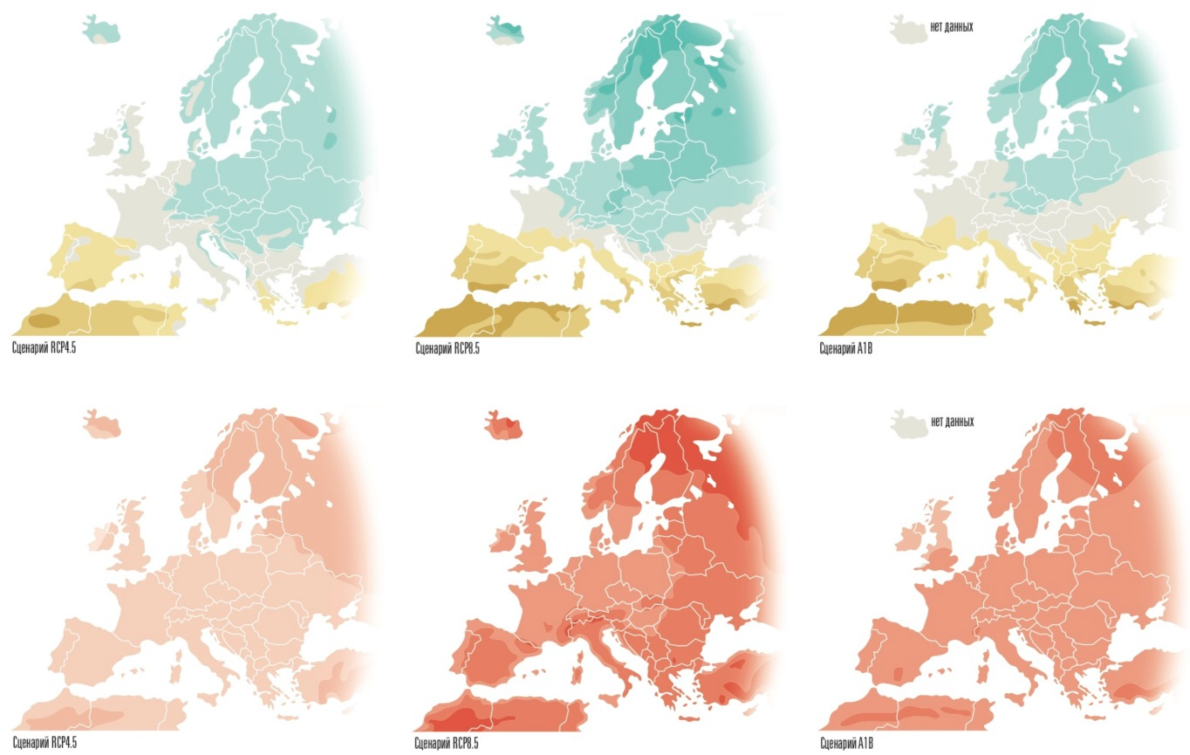
In recent years, the spread of cereal flies has expanded. Long-lasting warm autumn favored mass population during the emergence of winter crops and damage to plants by Swedish flies (*Oscinella* sp.). Due to climate warming and the expansion of corn acreage, the mass development of the stem moth (Ostrinia nubilalis Hbn.) has been registered in the Gomel and Brest oblasts, where stable foci of its high numbers and harmfulness were identified.

The trend of air and soil temperatures growth in July and August, increased frequency of droughts, and drying of the arable horizon contribute to mass reproduction and accumulation of both soil and low-prevalence species of phytophagous that used to have no practical significance before. In isolated crops of triticale and winter wheat at the farms of the Brest oblast foci with high numbers and harmfulness of the opomiza (*Opomyza florum* F.) were identified. In connection with the climate warming, changes in the dominance of the cereal leaf beetle species are observed. So, the cereal leaf beetle's habitat, that are found mainly in agrocenoses of grain crops on light soils of southern regions, is expanding in the north of Belarus. In 2012 - 2015, the blue pavilion, which shifted from the background to the dominant species (in 2016 dominated by the cereal leaf beetle) dominated the sowing of the northern parts of the country on soddy-podzolic and loamy soils. The main pockets of a high number of cereal leaf beetle were recorded in the Gomel, Minsk and some areas of the Mogilev and Grodno oblasts.

Recently, warm winters with little snow have been recorded in the south of Belarus, when soil temperatures below -6.5 ° C are not recorded. Therefore, in addition to the dominant soil-infecting pests (larvae of beetles, cereal leaf beetle, may bugs, etc.), the beetle-hulk or horsetail (*Anisoplia segetum Hrbst*., A. floricola F.) became a serious danger for crops, while more than 80% of its larvae]usually die when the soil freezes to a depth of 15 to 20 centimeters.

3.2 Expected climate change and its consequences[6]

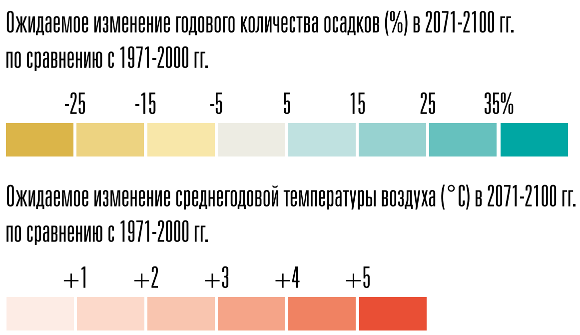
Most global climate models point to the expected increase in the maximum and minimum temperature in the future, an increase in the number of hot days - practically for the whole terrestrial part of the world; An increase in the number of cases of intense precipitation and a decrease in the number of days with low precipitation - for many regions in the extratropical latitudes of the Northern Hemisphere, a decrease in the number of cold days - practically for the entire terrestrial part of the world, a reduction in the amplitude of the diurnal temperature variation - for most regions. All these conclusions are typical for Belarus.



*сценарий - scenario

Picture 3.2.1 Expected climate change in Europe (UNECE and OSCE, 2015, based on Jacob et al., 2014)

Calculations for 2071 - 2100 compared to 1971 - 2000 based on the ensemble of EURO-CORDEX models according to the "representative concentration trajectories" of greenhouse gases in the atmosphere of RCP 4.5 and RCP 8.5 and the scenario of greenhouse gas emissions SRES A1B (from left to right).



Analysis of calculations based on a moderate and fairly likely scenario of climate change RCP4.5 shows a significant expected change in agroclimatic characteristics by the middle of the century: especially with regard to an increase in the duration of the warm period with a sum of air temperatures ≥0 ° C. By 2041-2060 its duration will increase on average by 35 days and will range from 280 to 310 days, and in the extreme south-west in the Brest region it will be 365 days (which

[6] The section is prepared based on materials by Melnik et al., 2017, Yakimovich et al., 2017, Kozyra et al., 2017

will lead to the disappearance of the winter in the classical sense). The duration of the growing season (≥5 ° C) and the period of active vegetation (≥10 ° C) will also increase, respectively, by 18 and 19 days on average. The sum of temperatures above 10 ° C will grow by an average of 480 ° C by 2041 - 2060 and will reach 2700-2800 ° C in the north and 3050-3250 ° C in the south of the country (see picture 3.2.8 below).

Table 3.2.1 Change in seasonal air temperature (°C) and precipitation (mm), obtained for the territory of Belarus using an ensemble of 31 models CMIP5 in relation to the base period of 1989-2015 for the scenario RCP4.5 (Melnik et al., 2017)

Period, years	**Temperature**				**Precipitation**			
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
2011 – 2030	0,9	0,9	0,5	0,7	4	-1	1	0
2021 – 2040	1,4	1,3	0,9	1,0	7	0	1	7
2041 – 2060	2,4	2,1	1,6	1,7	9	1	1	8

Most calculations indicate a probable insignificant increase in the amount of precipitation in the autumn and winter seasons. In spring and summer, it will not change much, but moisture supply in summer will decrease due to higher air temperature and transpiration by plants. Humidification of the territory of Belarus by the Selyaninov Hydrothermal Index (HDTI) for May - July will decrease and in about one third of the country's territory will amount to 1.0 - 1.2, which is typical for arid and weakly arid conditions. With an average index value of 1.0, the probability of arid and very arid conditions will be at least 50% (which will require constant activities on sandy and sandy loam soils to conserve moisture reserves or to select drought-resistant crops for them).

Table 3.2.2 Change in agroclimatic characteristics obtained for the territory of Belarus using the ensemble of 31 models of CMIP5 in relation to the base period of 1989-2015 for the scenario RCP4.5 (Melnik et al., 2017)

Period, years	**Variation from the period duration, days**			**Sum of air temperatures**		**HDTI variation**
	≥0°C	**≥5°C**	**≥10°C**	**≥5°C**	**≥10°C**	
2011 – 2030	10	7	9	172	186	-0,09 – 0,1
2021 – 2040	15	10	12	270	273	-0,1 – 0,2
2041 – 2060	35	18	19	466	480	-0,2 – 0,3

Calculations of seasonal air temperature, precipitation and agroclimatic characteristics for a more "tough" scenario of global climate change RCP8.5 show that in this case, the heat supply for the growing season will increase even more, and in summer, due to high temperatures and lack of moisture, the aridity of the territory will increase.

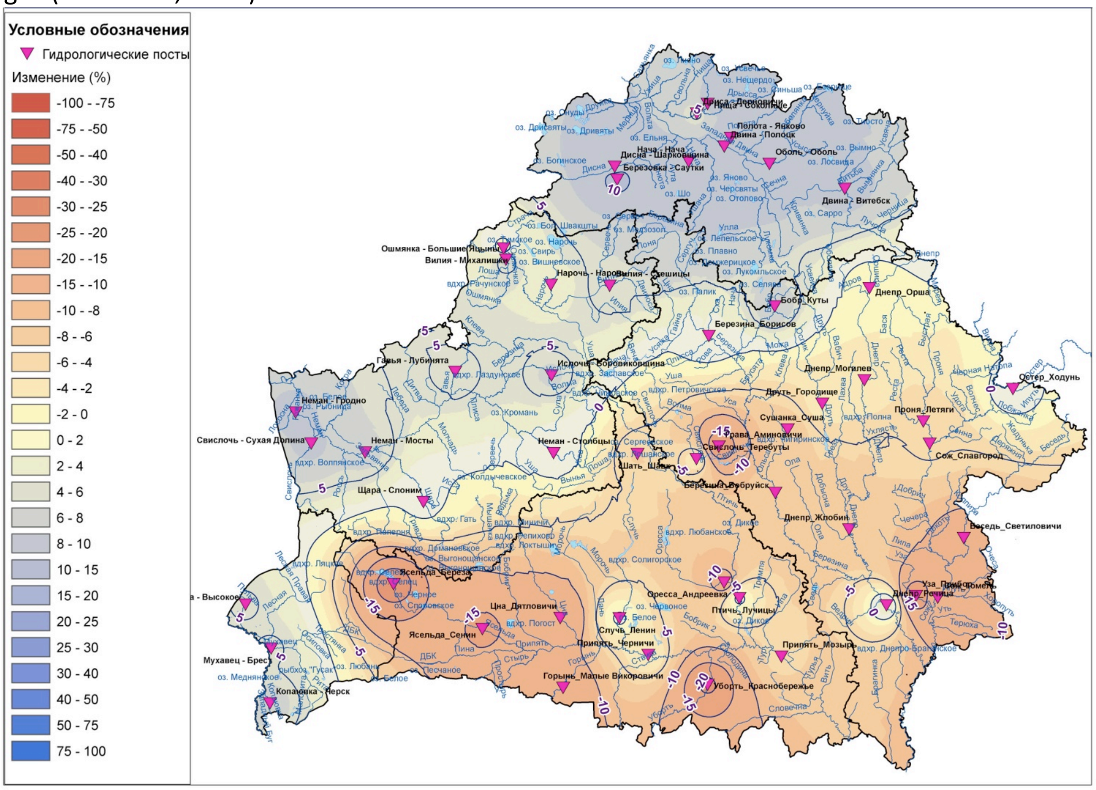
Table 3.2.3 Change in seasonal air temperature (°C) and precipitation (mm), obtained for the territory of Belarus using an ensemble of 31 models CMIP5 in relation to the base period of 1989-2015 for the scenario RCP8.5 (Melnik et al., 2017)

Period, years	Temperature				Precipitation			
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
2041 – 2060	3,1	2,6	2,3	2,5	10	4	-3	4

Table 3.2.4 Change in agroclimatic characteristics obtained for the territory of Belarus using the ensemble of 31 models of CMIP5 in relation to the base period of 1989-2015 for the scenario RCP8.5 (Melnik et al., 2017)

Period, years	Variation from the period duration, days			Sum of air temperatures		HDTI variation
	≥0°C	**≥5°C**	**≥10°C**	**≥5°C**	**≥10°C**	
2041 – 2060	54	24	26	645	660	-0,3 – 0,4

Associated with the expected changes in hydrometeorological characteristics, the forecast of changes in river runoff for the period up to 2035 allows us to talk about possible differently directed changes (CRICUWR, 2016).



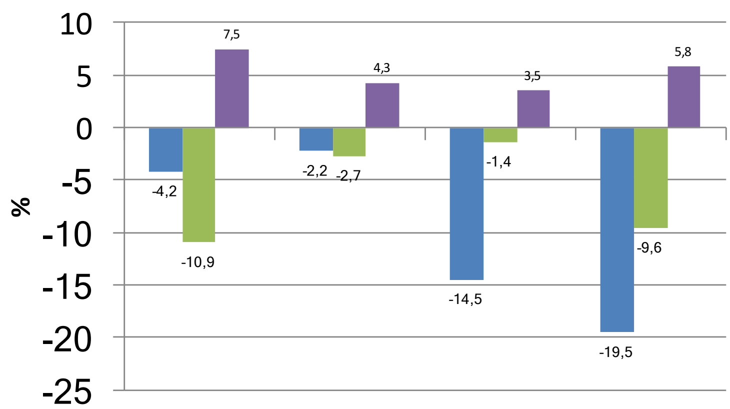
*Условные обозначения – Legend
Гидрологические посты – Hydrological stations
Изменения (%) – Changes (%)

Picture 3.2.2 Forecast change of mean annual runoff by 2035 (CRICUWR, 2016)

In the south and south-east of Belarus, the average annual runoff of rivers is expected to decrease, in the north and northeast, it is likely to increase. It is expected that the winter runoff of rivers in the whole country will increase due to thaws and active snowmelt (at the same time, snow cover thickness is expected to reduce in winter and reduce accumulation of moisture in the soil). A feature of the spring season will be a significant reduction in the spring flood in the south and east of the country. A particularly significant decrease in spring flow is expected in the upper reaches of the Pripyat and its tributaries (up to 30 - 25%) and in the basin of the Berezina (up to 20%). A significant decrease in the flow of rivers in the summer - by 20%, and in some regions - up to 40% in virtually all areas, except in the north of Belarus, is associated with the expected increase in air temperature and a decrease in the amount of precipitation. The autumn season is also characterized by a likely decline in river flow - up to 15%.

With sufficient moisture in conditions of a likely change in the amount and mode of precipitation and water flow characteristics, the predicted increase in the provision of crops with heat and the duration of the growing season will contribute to the expansion and improvement of the structure of crop production and the growth of agricultural potential. An extensive analysis of the results of calculations on the agricultural zone in Russia shows that under climatic changes according to the RCP4.5 scenario, bioclimatic potential in the first third of the century will increase by 8% compared to the current level, and by the end of the century - by 25%. Calculations for the central and north-western districts of Russia (closest to the conditions of Belarus) show an increase in the productivity of cereals for all periods under review.

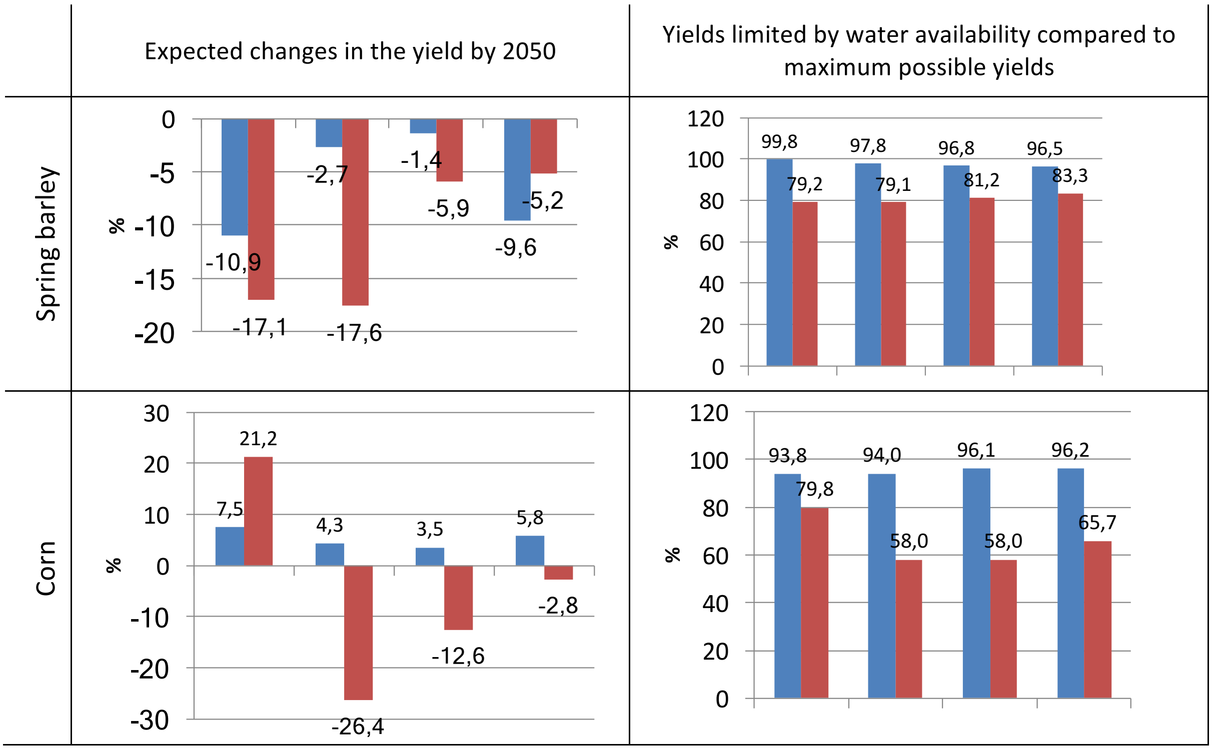
For the RCP8.5 scenario, this increase will be less significant. With an increase in the average annual temperature of more than 2 ° C and preservation of the current state of agriculture, the yield of cereals may drop by 5-6% by 2030, which can be overcome by changing varieties to later-ripening varieties and other adaptation measures. However, with the further development of global warming, agriculture of the southern and eastern regions of the country will face the problem of insufficient water availability and droughts, and by the end of the 21st century the bioclimatic potential and productivity of cereals can significantly decrease compared to the current level - up to 16% by the end of the century.



On the diagram, from left to right: Naroch, Orsha, Slutsk, Mozyr.
Colors: blue - rapeseed, green - spring barley, purple - corn

Picture 3.2.3 Expected changes in the yield on clay-loam soils by 2050 compared to 2010 under the RCP4.5 scenario (Kozyra et al., 2017)

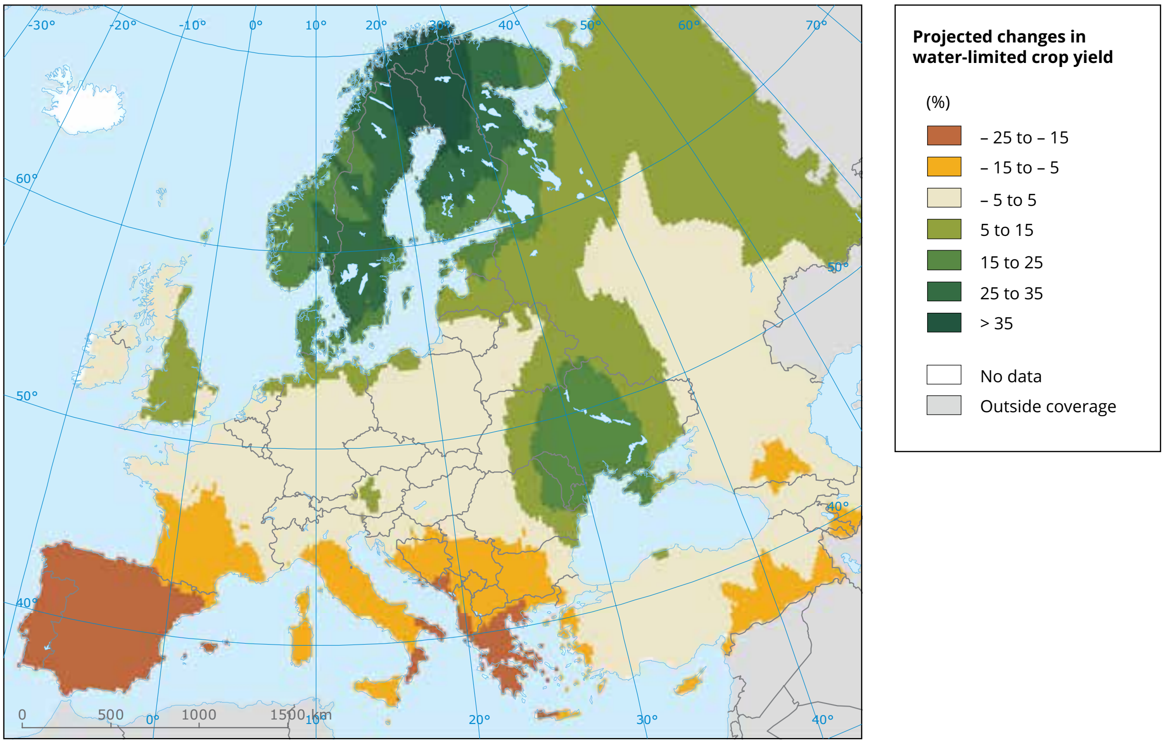
However, a differentiated analysis of the expected agricultural productivity (pictures 3.2.3 to 3.2.4) shows that under the conditions of the RCP4.5 scenario, the lack of moisture due to a deficit of precipitation and runoff can in practice significantly reduce the effect of potential yield growth triggered by the warming. Modeling for several sites in different parts of Belarus (Naroch, Orsha, Slutsk and Mozyr) showed that the changes can vary significantly for different crops, soil conditions, and depending on the supply of moisture. In the worst case, the decline in barley, rape and maize yields on sandy soils by 2050 could reach 15-25% of the 2010 level. In the best case, the yield of maize in the north-west of the country can grow by 10 - 20%. The fall in the yield of rapeseed and barley due to inadequate moisture supply is expected at all sites chosen for modeling.



On the diagrams, from left to right: Naroch, Orsha, Slutsk, Mozyr.
Colors: red - sandy soils, blue - sand-loam soils

Picture 3.2.4 Expected changes in the yield of spring barley and corn and comparison of yields thereof limited by water availability to maximum possible yields on various soils by 2050 against 2010 under the RCP4.5 scenario (Kozyra et al., 2017)

Similarly, analysis in the conditions of implementation of the global greenhouse gas emissions scenario SRES A1B for limited by moisture content combined yields (taking into account the current spread of crops) of wheat, maize and soybeans in Europe shows its possible changes in the territory of Belarus from -5% to + 15% by 2050 compared with 1961 - 1990 (European Environment Agency, 2017).



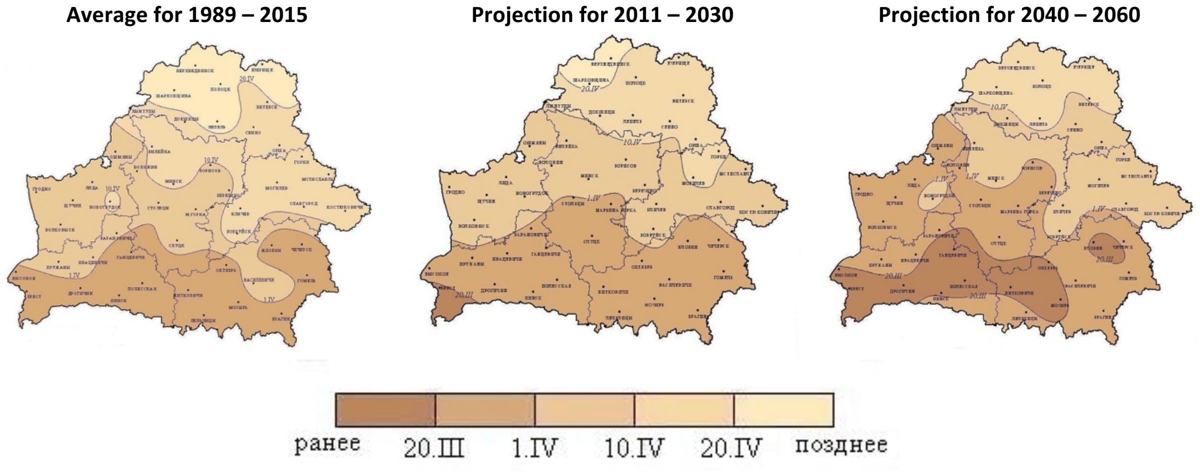
Calculations for 12 climatic models, SRES A1B scenario.

Picture 3.2.5 Average change (%) of limited by moisture content combined yields of wheat, maize and soybeans in Western and Central in 2050 compared to 1961 – 1990
(European Environment Agency, 2017 based on Iglesias et al., 2012, Tsiscar et al., 2011)

Agricultural production losses will also be caused by the gradual expansion of the borders of habitats and areas of mass reproduction and harmfulness of pests, including the Colorado beetle, in the northern and eastern directions. High probability of acclimatization in the territory of Belarus of the western corn beetle (*Diabrotica virgifera* LeConte) is forecasted, the optimal conditions for which are created by the sum of active temperatures from 2400 to 2600 ° C.

Picture 3.2.3 The centers of invasion of the western corn bug in the Brest region in 2009 - 2014 (Yakimovich et al., 2017)

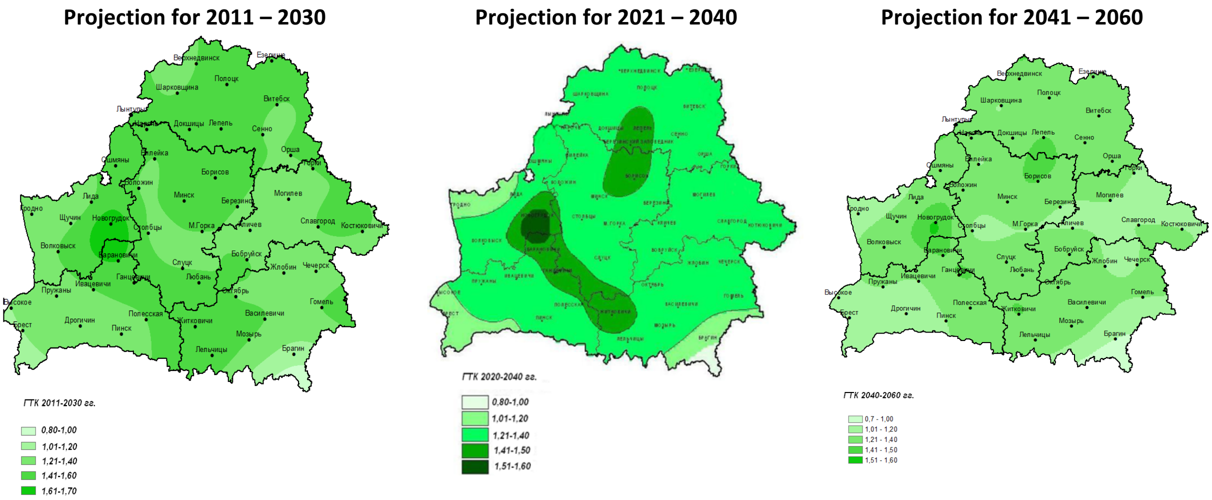
The potential change in agrophenological characteristics illustrates the spatial analysis of soil conditions in the territory of Belarus for the RCP4.5 scenario. Calculations show that by 2050 the timing of sowing of early spring crops, due to the drying of the soil to a soft plastic state, will start in the south of the country on average by 20, and in the north - by 10 days earlier than at present.



*Ранее – before
Позднее - later

Picture 3.2.6 Timeline of occurrence of the soft plastic state of the soil (beginning of sowing of early spring crops) for the RCP4.5 scenario (Melnik et al., 2017)

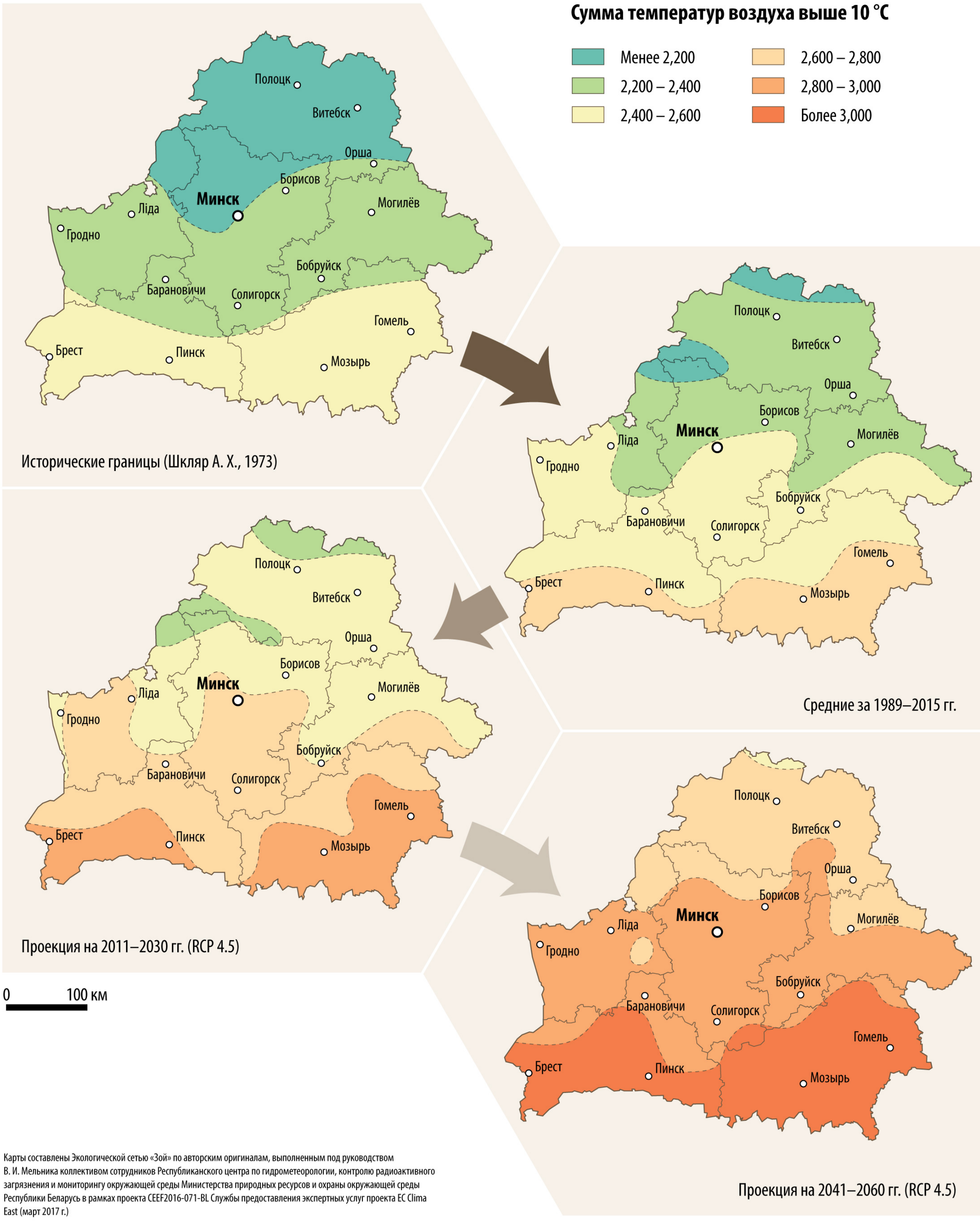
For a comprehensive study of the shift of large agro-climatic zones in the territory of Belarus according to the calculated forecast agroclimatic indicators (the sum of temperatures above 10 ° C and the Selyaninov HDTI during the growing season), maps of the spatial distribution of these characteristics.



*ГТК - Selyaninov HDTI

Picture 3.2.7 Distribution of moisture of the territory of Belarus under the Selyaninov HDTI during the growing season under the RCP4.5 scenario (Melnik et al., 2017)

Their analysis shows that as a result of the expected warming according to the RCP4.5 scenario, by 2030 the former Central agroclimatic region with the sum of active temperatures of 2,200 - 2,400 ° C will actually disintegrate, and its place will be occupied by the former Southern region (2,200 to 2,600°C). Under this scenario maize for grain and sunflower will be available for cultivation in the whole territory of Belarus. The New agroclimatic region (2,600 - 2,800 ° C), which had appeared in the south of the country by the end of the last century, will move far to the north and take the place occupied by the Southern region at the moment, and even warmer regions with a sum of active temperatures exceeding 2,800 ° C and even 3,000 ° C will appear in its place.



*Сумма температур воздуха выше 10°C – Sum of temperatures above 10°C
Менее 2,000 – Below 2 000
Более 3,000 – Above 3 000
Исторические границы (Шкляр А.Х., 1973) – Historical borders (A.H. Shklyar)
Средние за 1989 – 2015 гг. – Average for 1989 - 2015
Проекция на 2011 – 2030 гг. – Projection for 2011 – 2030
Проекция на 2041 – 2060 гг. – Projection for 2041 – 2060

Picture 3.2.8 Historical and expected change in borders of agroclimatic zones in Belarus for the RCP4.5
(based on Melnik et al., 2017)

Table 3.2.5 Characteristics of agriculture and existing geographical analogues (in italics) of agroclimatic zones of Belarus (based on Melnik et al., 2017)

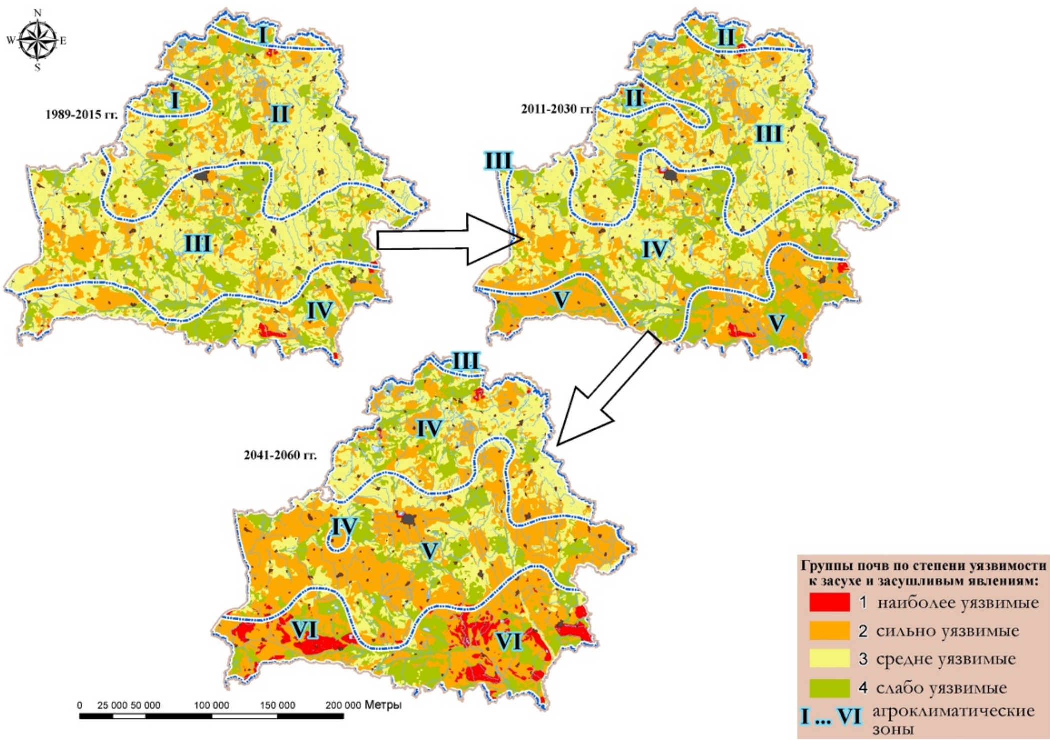
< 2200 °C	Cereals (winter and early spring), potatoes, long-stalked flax, fodder crops (perennial and annual grasses), vegetables (table beets, carrots, white cabbage), corn for silage *North of the Vitebsk oblast*
2200 – 2400 °C	Cereals (winter and spring, including buckwheat, corn, leguminous crops), potatoes, long-stalked flax, rapeseed (winter and spring), sugar beet, fodder crops (perennial and annual grasses), vegetables in open and closed ground *Center of the Mogilev, Minsk, Grodno oblasts*
2400 – 2600 °C	Cereals (winter and spring, including buckwheat, corn, including grains of early ripening varieties, leguminous crops), potatoes (except for middle and late varieties), flax, forage crops (annual and perennial grasses), rapeseed (winter and spring), sugar beet, vegetables (carrots, onions, peas, tomatoes, cucumbers, garlic) *Center, west, east, south of Belarus (exclusive of the extreme south), central Ukraine (Vinnitsa, Kiev), south of the European part of Russia (Penza, Voronezh)*
2600 – 2800 °C	Cereals (including corn, soy, buckwheat, millet), sunflower, sugar beet, vegetables in the open and closed ground (onions, table beets, carrots, cabbage, vegetable peas, tomatoes, cucumbers, garlic, asparagus beans, cauliflower, broccoli, eggplant), horticulture, fodder crops *South of the Brest and Gomel oblasts, central Ukraine (Cherkassy, Sumy), south of the European part of Russia (Samara)*
2800 – 3000 °C	Cereals (spring and winter wheat and rye, millet, barley, oats, buckwheat, corn), peas, sunflower, sugar beet, rapeseed, soybeans, vegetables, melons and gourds, fruits, fodder crops *Central Ukraine (Poltava, Kharkiv, Kirovograd, Lugansk), south of the European part of Russia (Saratov, Volgograd)*
> 3000 °C	Cereals (wheat, barley, leguminous crops, corn, sorghum, millet), soybeans, sugar beet, rapeseed, vegetables, fruits (including grapes), melons and gourds, fodder crops *South of Ukraine (Donetsk, Lugansk), Predkarpatie (Chernovtsy, Ternopil), south of the European part of Russia (Rostov-on-Don, Krasnodar)*

Findings of the soil vulnerability analysis in the considered agroclimatic zones indicate a gradual increase in the share of the most vulnerable and highly vulnerable soils in zones with a sum of temperatures over 2,800^{0}C. This trend will primarily affect the southern and, partially, central regions of Belarus with a significant share of light mineral and drained soils.

Table 3.2.6 Distribution (%) of groups of soils with various degree of exposure to droughts and arid phenomena in agroclimatic regions of Belarus (Melnik et al., 2017)

Agroclimatic zones with sums of temperatures above 10 °C	Degree of soil exposure			
	Highest	Strong	Medium	Low
1989 – 2015				
< 2200°C	0,08	1,52	1,48	1,32
2200 – 2400°C	0,12	7,14	21,92	6,81
2400 – 2600°C	0,07	8,09	23,00	10,35
2600 – 2800°C	0,37	4,27	7,15	5,61
2011 – 2030 (RCP4.5 scenario)				

2200 – 2400°C	0,12	1,54	1,62	1,67
2400 – 2600°C	0,04	7,48	23,84	7,01
2600 – 2800°C	0,12	10,19	18,31	10,54
2800 – 3000°C	0,42	11,94	0,58	4,63
2041 – 2060 (RCP4.5 scenario)				
2400 – 2600°C	0,00	0,20	0,16	0,09
2600 – 2800°C	0,16	8,62	12,81	4,34
2800 – 3000°C	0,27	24,48	12,15	7,49
> 3000°C	4,92	14,55	1,72	8,04



*Группы по степени уязвимости к засухе и засушливым явлениям –
Groups depending on exposure to droughts and arid phenomena
Наиболее уязвимые – Most exposed
Сильно уязвимые – High exposure
Средне уязвимые – Medium exposure
Слабо уязвимые – Low exposure
Агроклиматические зоны – Agroclimatic zones

Picture 3.2.9 Existing and future (RCP4.5 scenario) exposure of Belarus' soils to droughts and arid phenomena (Melnik et al., 2017)

4 PRIORITIES FOR ADAPTATION OF BELARUSIAN AGRICULTURE

4.1 General Provisions[7]

Among the core policy documents of the Republic of Belarus outlining the state policy in the area of climate change and mitigation of its consequences for different branches of economy, including agriculture, the following should be highlighted:

- The National Social and Economic Development Program until 2020[8], that outlines the main areas of state policy related to climate change and certain issues of adaptation to climate change;
- State Program for Sustainable Development of Rural Areas in 2011 – 2015[9];
- State Program for Development of Agrarian Business in the Republic of Belarus in 2016 – 2020[10];
- Strategy for Environmental Protection in the Republic of Belarus for the Period until 2025[11], that sets out the priority areas of the state environmental protection policy and, alongside with solving other tasks, minimization of impact on climate and adaptation to change thereof;
- Strategy for Development of Hydrometeorological Activity and Activity in the Area of Environmental Monitoring in the Republic of Belarus for the Period until 2030[12];
- and, finally, the abovementioned National Program of Climate Change Mitigation Measures for 2013-2020, in the framework of which a number of activities and scientific research on climate change issues and adaptation measures, including agriculture, are planned[13].

In the framework of implementation of provisions of these policy documents, concrete measures to adapt agriculture to climate change are already in progress in Belarus today. In recent years, acreage of corn left for grain has increased significantly, corn-milling enterprises have been built and are operating, and at the moment the country is almost completely self-sufficient in terms of corn seeds. The acreage of rapeseed for seeds has increased. In the southern regions of the country winter barley is introduced, soybean is sown every year, and the acreage of sunflower, vegetable peas, sugar corn, and bean sprouts is being expanded. Industrial cultivation of onions in an annual culture has been mastered, as well as that of early heat-loving potato varieties. Creation of industrial plantations of grapes is in progress, and work is underway to expand the area of melons and gourds.

The priorities for further adaptation of Belarusian agriculture to climate change in the 21st century, should, in particular, include the following:

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[7] The section is partially based on the following materials: Melnik, 2015, Kozeltsev, 2016, Yakimovich et al., 2017, Kozyra et al., 2017.
[8] Approved by the National Commission of the Republic of Belarus on Sustainable Development, protocol # 11/15. ПР dated May 6, 2014
[9] Approved by Decree of the President of the Republic of Belarus # 342 dated August 1, 2011
[10] Approved by Resolution of the Council of Ministers of the Republic of Belarus # 19 dated March 11, 2016
[11] Approved by Resolution of the panel of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus # 8-P dated January 28, 2011
[12] Approved by Resolution of the panel of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus # 124 dated December 20, 2014
[13] Approved by Resolution of the Council of Ministers of the Republic of Belarus # 510 dated June 21, 2013 as amended by Approved by Resolution of the Council of Ministers of the Republic of Belarus # 444 dated May 8, 2014.

- in-depth assessment of changes in climatic and agroclimatic characteristics during the warming period and a new agroclimatic zoning of the country's territory to take into account changes in the agroclimatic conditions of the growth of agricultural crops in agricultural practices at all levels;
- changes in land use, taking into account the vulnerability and exposure of agricultural soils to the intensification of droughts and arid phenomena, densification, water and wind erosion (including increased level of landscape diversity, especially in areas prone to wind erosion), revision of the cadastral land valuation system, with due account of climate change;
- introduction of water-saving technologies and expansion of irrigated farming areas, modernization of irrigation and drainage networks and infrastructure with account of the expected changes and seasonal redistribution of water flow, introduction of an integrated water resources management system in the country, taking into account the priorities of their use in the interests of different sectors;
- optimization of acreage, crops and agrotechnical methods, as well as species composition, nutrition and conditions of livestock keeping in the light of changing climatic conditions; strengthening and development of the activities of plant protection services, especially at the borders of present-day habitats of the main climate-dependent pests and pathogens of agricultural crops;
- strengthening research and innovation activities in the field of climate change impact on agriculture, monitoring climate change, adverse weather events, surface and groundwater and soil conditions, as well as rapid dissemination of information about them, raising awareness of authorities, large and private households and the public about climate change issues, opportunities and ways of adaptation to it;
- development of the institutional framework for adaptation to climate change, including improvement of regulatory and economic support for economic adaptation in agriculture, strengthening interaction between government bodies and other stakeholders through establishment of permanent interdisciplinary mechanisms for the preparation and implementation of specific recommendations and measures in this area;
- increasing the number of farms, redistribution of land with account of specialization of agricultural production and increasing the share of the private sector in agriculture, creating conditions for attracting businesses to participate in climate change mitigation and adaptation to it;
- introduction of new progressive lines of agricultural production (including environmentally safe organic farming) and planning for further development of the industry, taking into account changes in the conditions of agriculture in other countries, the evolution of the agricultural market and the external economic situation.

Certain areas mentioned above have been developed in more detail under the European Commission’s Clima East project in Belarus and are reviewed in the sections below.

4.2 Sectoral Dimension of Adaptation: Crop Production and Water Melioration[14]

The use of favorable effects of climate warming is possible only in concert with implementation of adaptation measures aimed at preventing (reducing) losses caused by its negative consequences. A complex, multifactorial approach is needed to effectively adapt the crop production in Belarus. Of paramount importance is the development of a comprehensive strategy of economically sound adaptive intensification of the whole system of agriculture, one of the tasks of which is to improve the fertility and phytosanitary state of soils with the effective use of renewable and low-cost natural processes. With sufficient regulatory and logistical support, this way will allow to obtain economically justified, ecologically safe high-quality crop production.

It is necessary to expand the network of sites on which breeding work is conducted, and radically improve the methodological level of field research. To increase the informative value and manageability of breeding processes, modern information technologies should be implemented promptly.

One of the most important tasks is improvement of technologies for cultivating agricultural crops. Optimum sowing time and agrotechnical measures for crop care, as well as high-quality and water-saving soil cultivation will improve the resistance of crops to changing weather and climate conditions. In connection with improvement of heat supply and in order to reduce the negative impact of arid phenomena, it is advisable to increase the share of more heat-loving and drought-resistant crops in the structure of sown areas. In the group of cereals, preference should be given to winter crops that able to make maximum use of spring reserves of soil moisture and are less exposed to summer drought than spring crops.

General measures for adapting crop production

- Improvement of the general cropping culture and agrotechnical modernization by placing crops after the best predecessors in the crop rotation system; cultivation of high-yielding varieties of intensive type with good grain quality; improving the provision of plants with mineral nutrition elements, taking into account their content in the soil; fractional application of nitrogen fertilizers during the growing season according to soil and plant diagnostics data;
- Timely and high-quality implementation of technological methods aimed at protecting the soil from erosion, accumulation of moisture, creation of favorable physical conditions for development of crops;
- Radical change in grass harvesting, use of improved hayfields and cultivated pastures, guaranteed self-sufficiency with grass seeds;
- Expedient introduction of drought-resistant crops, including those uncommon and unconventional for Belarus, such as millet, Turkestan millet, diploid rye, deer vetch, alfalfa, sweet clover, winter turnip rape, sorghum-sudangrass hybrids, etc.;
- Efficient use of early spring moisture reserves (so-called "avoiding drought") by shifting the timing of sowing of spring crops to an earlier time);
- Increasing the autumn application of organic fertilizers (manure, compost), the use of perennial legumes and stubble crops as compensators for the deficiency of organic substances and a means of improving the water-holding capacity of soils, their water and heat regime;

[14] The section is prepared based on the following materials: Yakimovich et al., 2017.

- Use of modern technologies for irrigation of cultivated pastures and planting vegetables to ensure high yields;
- Increasing the water storage capacity of soils (especially light sandy soils) by introducing agrotechnical techniques that minimize surface evaporation and degradation of the fertile layer;
- The expansion of heat-loving crops in the south of Belarus (maize, alfalfa, hybrid clover, beet fodder, etc.) for the needs of the country.

One of the most important consequences of climate change for agriculture will be the impact thereof on the incidence, scale and severity of plant diseases, which requires adjusting the organization of plant protection activities with due account of the timing, benefits and effectiveness of chemical, physical and biological disease control measures. In general, the task of adapting disease control measures to climate change is likely to not significantly differ from adaptation to the achievements of scientific and technological progress and changes in the economic structure that are already required in current activities under the concept of integrated plant protection. Under the new conditions, the demand for a diverse, flexible and sustainable cropping system, capable of efficiently operating under changing conditions, will be even higher.

Plant protection adaptation measures

- Strengthening the set of measures aimed at protecting the territory of Belarus from importing and spreading pests, pathogens and weeds that are quarantine for the country;
- Potential increase in the use of plant protection products in connection with the expected increase in the vulnerability of crops to pests and diseases;
- Replacement of traditional pesticides with new plant protection products, more intensive development of works related to the search, creation and screening of a new generation of plant protection chemicals, biologically active substances produced by living organisms and their synthetic analogues with high environmental safety and efficiency against pests, phytopathogens and weeds;
- A more intensive development of environmentally oriented measures to limit the harmfulness of pests, diseases and weeds (development of environmental thresholds for damage, sowing green manure crops, clarification of the number of treatments, etc.), including through strict regulation and control of the use of pesticides and chemical treatment of crops;
- Introduction of the system of "accurate" farming for cost-effective and environmentally safe application of plant protection products by regulating preparations by their application rate and quantity using information technologies that allow calculating the introduction of plant protection products taking into account the level of weediness, spread of diseases and pests;
- Study, development and production mastery of methods and systems to ensure the resistance of agroecocoenoses to biotic stresses, optimize and stabilize the phytosanitary condition of agricultural lands using information technology;
- Development of research to develop better, faster and more automated methods for identifying pests, pathogens and weeds, diagnosing and accounting for their numbers, data processing, monitoring and forecasting.

Given the expected climate change, water reclamation will play an extremely important role in adapting to agriculture and, above all, crop production. The need for expanding the irrigation network, reconstruction and modernization of its infrastructure is very likely. Similarly, upgrading surplus water disposal systems will be required to prevent and reduce damage from increasingly occurring high water periods and floods.

It is important to forecast the trends in the development of negative processes and degradation of irrigated lands, their impact on adjacent areas, character of the seasonal, annual and long-term dynamics of the level, mineralization and chemical composition of groundwater, with due consideration of climate change. Dynamics of moisture reserves in the root layer of the soil during the growing season, ameliorative situation in the dynamics of its development, and the forecast of possible changes in subsequent years should be monitored and assessed on a regular basis.

The presence of long-term forecasts and due account of the direction of climate change allows carry out the necessary measures for the accumulation of water or, conversely, the removal of excess water by means of reclamation systems in a timely manner, however, change in the relevant design parameters should be reflected in the engineering and construction regulatory documents.

Adaptation measures in the area of water melioration and protection against floods

- Modernization and optimization of land reclamation system bearing in mind the long-term climate change trends and water use priorities within the framework of the integrated water resources management strategy of Belarus;
- Involvement of river floodplains into economic use with provision for the probability of flooding in the face of climate change, informing the population and local authorities about the long-term risk of flooding floodplain territories and strengthening personal responsibility for their use at the legislative level, as well as insurance against flood damage;
- Organization of timely notification of the population and local authorities about the danger of floods using modern information technologies;
- Expand the practice of restoring natural riverbeds and floodplains as an economically and environmentally efficient measure to protect against floods and reduce damage from them;
- Transfer to other categories of land for which reconstruction of land reclamation systems and structures is unfeasible for environmental and economic reasons;
- Restoration of lands damaged as a result of large-scale drainage land reclamation (reduction of areas with a destroyed fertile layer, application of forest melioration to reduce wind erosion, monitoring of the state of drained peatlands in fire danger periods, etc.).

4.3 Sectoral Dimension of Adaptation: Livestock and Fish Farming

Detailed study of adaptation measures for livestock and fish farming in Belarus requires additional studies that were not carried out as part of preparation of this document. The following summarized adaptation measures in the area of intensive and pastoral livestock farming follow the recommendations of the European Topic Center on Climate Change, Sustainability and Adaptation (European Environment Agency, 2017).

Adaptation measures for intensive livestock farming

- Improvements in ventilation and other conditions in animal keeping areas;
- Breeding for the purpose of developing breeds of animals with higher resistance to heat stress, new diseases and their spreaders;
- Monitoring the health status of farm animals, if necessary - strengthening the limited use of antibiotics, new feeds, nutritional supplements and treatment methods;
- Improving the fodder base and increasing the efficiency of assimilation of nutrients from feeds, taking into account the forecast of their composition in the conditions of climate change;
- Increasing the diversity of local feeds, using local high protein foods;
- Limiting the movement of agricultural transport to reduce the risk of soil compaction;
- Increasing the efficiency of collection, supply and use of water and, in general, water management for intensive livestock.

Adaptation measures for pasture livestock farming

- Breeding to develop breeds of animals with better resistance to heat stress, new diseases and their spreaders;
- Monitor the health status of farm animals, if necessary - increase the limited use of antibiotics and treatments;
- Optimize land use to reduce the impact of new diseases and their spreaders;
- Increasing the efficiency of nutrient assimilation, taking into account the forecast of the composition of the forage base in the context of climate change, determining the need for additional nutrition;
- Optimization of the structure of hayfields and pastures to improve their resistance to extreme weather conditions, including the use of a mixed land use structure with forest vegetation, possibility of growing vegetables, etc.;
- Improving the organization of animal grazing, providing pastures with artificial and natural protection from the sun, limiting grazing in wet periods;
- Improving efficiency of collection and supply of water and management of water resources for pasture livestock farming needs.

First and foremost, adaptation of fish farming is connected with improving stability of the fish herd to climate change, as well as maintaining the state of natural and artificial water bodies sufficient for fish farming and fishing. The proposed generalized measures (Yakimovich et al., 2017) are intended to solve these problems.

Adaptation measures for fish farming

- Constant monitoring of ichthyofauna, its changes and the state of the aquatic environment in the face of climate change;
- Using the potential of breeding, farming and using new fish species to adapt the ichthyofauna structure;
- Expansion of the network of artificial reservoirs and application of aquaculture technologies;
- Technological measures to maintain the required water quality in fishponds (aeration, flow increase, chemical methods);
- Strengthening the protection of water bodies used for fish farming and fisheries, as well as their water protection zones, to minimize the impact of climate change on water quality and the state of the commercial ichthyofauna;
- Effective supervision of water use and its optimization;
- Regulation of fisheries management in the light of climate change.

4.4 Territorial Dimension of Adaptation: Regional Priorities for Belarus

The map demonstrating the shift of agroclimatic zones in the territory of Belarus shown above (picture 3.2.8) shows that by the middle of the century the local conditions of agricultural production will change significantly. According to the relatively mild scenario of global warming, by 2060 the modern conditions of the south of the country will remain only in its extreme north (in the Vitebsk region), while in most of Belarus agroclimatic parameters will be close to the current conditions of the center and south of Ukraine, the Volga, the Don and Kuban basins. While some of the expected changes will be positive from the point of view of agriculture, their use will be possible only with adequate and sufficient adaptation to local conditions, first of all, from the point of view of the quality of the land fund and the perspective provision of territories with water resources. Tables 4.4.1 to 4.4.3[15] summarize the main impacts of climate change for the regions of Belarus and their respective adaptation priorities in general and for specific time periods.

Table 4.4.1 Agroclimatic zones and long-term adaptation priorities for agriculture in oblasts of Belarus

	VIT	GRO	MIN	MOG	BRE	GOM
Shift in agroclimatic zones						
Initial status: 1989 – 2015	● turquoise ● green	● turquoise ● green ● yellow	● turquoise ● green ● yellow	● green ● yellow	● yellow ● light peach	● yellow ● light peach
Short-term outlook: 2011 – 2030	● green ● yellow	● green ● yellow ● light peach	● green ● yellow ● light peach	● yellow ● light peach	● yellow ● light peach ● peach	● peach ● orange
Medium-term outlook:: 2031 – 2060	● yellow ● light peach ● peach	● light peach ● peach	● light peach ● peach ● orange	● light peach ● peach	● peach ● orange	● peach ● orange
► Adaptation to general climate change consequences						
Increase in frequency / intensity of showers, hail, hurricanes;	•	•	•	•	•	•
Increased risk of floods;	•	•	•	•	•	•
Increased risk of forest fires;	•	•	•	•	•	•
Development of pests and pathogens;	•	•	•	•	•	•
Invasive plant species and animals.	•	•	•	•	•	•
► Watering of drought-sensitive soils						
With prevalence of soils with medium exposure		•	•	•		
With prevalence of soils with high exposure					•	•
► Adaptation to a possible change in the conditions of agricultural production						
Favorable conditions for heat-loving crops	•	•	•	•	•	•
Increased productivity of cereals	•	•	•	•	•	•
Improvement of livestock fodder base		•	•	•	•	•
Deterioration of conditions for keeping animals		•	•	•	•	•

Note; names of oblasts are abbreviated; amounts of temperatures exceeding 10 °C in agroclimatic zones –

turquoise	green	yellow	light peach	peach	orange
< 2200 °C	2200 – 2400 °C	2400 – 2600 °C	2600 – 2800 °C	2800 – 3000 °C	> 3000 °C

[15] Tables for the section were prepared with the contribution of M. Falaleeva based on Melnik et al., 2017

Table 4.4.2 Priorities for adaptation of agriculture in oblasts of Belarus for 2011 – 2030

	VIT	GRO	MIN	MOG	BRE	GOM
Agroclimatic zones ►	● ●	● ● ●	● ● ●	● ●	● ● ●	● ●
► The need to expand irrigation practices						
With a decrease in the moisture content of soils;	•	•	•	•	•	•
When droughts and arid events intensify;		•	•	•	•	•
► Using new opportunities to plant						
- second crop of fodder crops	•	•	•	•	•	•
- buckwheat	•	•	•	•		
- sugar beet	•	•	•	•		
- corn left for grain	•	•	•	•	•	•
- soybeans					•	•
- sunflower					•	•
- millet					•	•
- sorgo					•	•
- melons and gourds					•	•
- fruits and vegetables in the open ground	•	•	•	•	•	•

Table 4.4.3 Priorities for adaptation of agriculture in Belarus for 2041 – 2060

	VIT	GRO	MIN	MOG	BRE	GOM
Agroclimatic zones ►	● ● ●	● ●	● ● ●	● ●	● ●	● ●
► The need to expand irrigation practices						
When droughts and arid events intensify	•	•	•	•	•	•
► Adaptation to changed conditions for plant production						
Opportunities to increase overall productivity	•	•	•	•	•	•
Opportunities to grow southern cultures	•	•	•	•	•	•
Potential reduction in the yield of potatoes, flax	•	•	•	•	•	•
► Using new opportunities to grow						
- second crop of fodder crops	•					
- buckwheat	•					
- sugar beet	•					
- corn for grain	•	•	•	•	•	•
- soybeans	•	•	•	•	•	•
- sunflower	•	•	•	•	•	•
- millet	•	•	•	•	•	•
- sorgo	•	•	•	•	•	•
- melons and gourds	•	•	•	•	•	•
- fruits and vegetables in the open ground	•	•	•	•	•	•

Note; names of oblasts are abbreviated; amounts of temperatures exceeding 10 °C in agroclimatic zones –

< 2200 °C	2200 – 2400 °C	2400 – 2600 °C	2600 – 2800 °C	2800 – 3000 °C	> 3000 °C

4.5 Institutional Dimension of Adaptation: Organic Farming[16]

Environmentally friendly "organic" farming allows to improve environmental sustainability of production, the quality of environment and attractiveness of agricultural products in foreign markets at the same time. Its methods and enterprises that implement them are well adapted to climate change through the use of traditional skills and farming experience. The knowledge and skills accumulated in this field reduce the dependence on resources and are important for managing complex agroecosystems, breeding varieties of seeds and livestock adapted to local conditions, production of fertilizers (compost, manure, green manure) and inexpensive plant protection products of natural origin. Applying "organic" methods for soil cultivation adapts it to extreme weather conditions, allowing it to retain more rain water. Broad diversity of "organic" farms (crops, fields, crop rotations, landscapes, types of agricultural activities and their combinations within individual farms) significantly increases their sustainability, inter alia, from the point of view of pest prevention.

"Organic" farming also has significant potential for reducing greenhouse gas emissions through conservation of carbon stocks in the soil, reducing erosion, reducing the density of farm animals, integrating crop production with livestock farming reducing the consumption of fossil fuels per hectare of land and per kilogram of output by eliminating synthetic (including nitrogen) fertilizers.

Belarus has significant potential for boosting this branch of agriculture, which is partially implemented in the draft law "On the production and circulation of organic products." The working group on development of "organic" farming includes representatives of interested organizations, scientific institutions and farmers that produce "organic" products.

On top of improving the regulatory framework, further development of “organic” farming in the country requires advanced development of scientific research and introduction of findings thereof into practice, as well as retraining agricultural producers and raising awareness of potential customers about "organic" products.

Measures of adaptation through the promotion of “organic” farming

- Further development of legislation and drafting targeted state programs in the field of "organic" farming;
- Establishment of a certification system in accordance with the requirements of the International Federation of Organic Agriculture Movements (IFOAM) and of a state system for labeling "organic" products;
- Promotion of scientific research in the field of "organic" farming;
- Preparation of training programs for secondary and higher education institutions;
- Information campaigns in the media for farmers and the general public.

[16] The section is prepared based on materials by N. Parechyna (http://ecoidea.by/ru/organic-farming) and Yakimovich et al., 2017.

4.6 Institutional Dimension of Adaptation: Science and Innovation[17]

The innovative process in agriculture has special features that can be attributed to the fact that the industry is based on the use of land resources as the main means of production and on participation in the process of production of living organisms. In this respect, the use of innovations related to adaptation of agriculture to climate change should contribute to development of new technologies for cultivation of domestic plants, especially labor-intensive ones, new technologies for keeping animals, etc. In the Republic of Belarus, fundamental scientific research related to adaptation measures in agriculture, is carried out mainly within the framework of state programs of scientific research (SPSR). To solve the most significant national economic, environmental and social problems, state scientific and technical programs (SSTP) are developed, a special place among which in the reviewed context belongs to the State Scientific-Technical Program “Agropromcomplex” (subprogram "Agropromcomplex - sustainable development").

Table 4.6.1 Main outcomes of the SPSR and the SSTP “Agropromcomplex” related to adaptation of agriculture to climate change consequences (2011 – 2015)

State programs of scientific research (SPSR) ▸	1	2	3	4
Accounting for agroclimatic conditions in the planning of agricultural production	•			•
Development of breeding of new highly productive varieties and hybrids resistant to diseases, winter crops, heat-loving, wind-resistant, and drought-resistant crops under climate change conditions	•			•
Assessment, prevention and mitigation of the effects of soil degradation in the context of climate change	•			•
Improvement of irrigation systems, water resource management, water-saving soil cultivation technologies	•			•
Development of measures to protect crops from pests, weeds and diseases		•		•
Development of biotechnologies for soil restoration, breeding of winter crops, heat-loving, wind-resistant, drought-resistant, and disease-resistant crops, improving fertilizer efficiency in the face of climate change		•	•	
Breeding of winter-resistant, drought-resistant and wind-resistant fodder crops directly for livestock needs		•		•
Development of resource-saving, low-cost technologies for keeping livestock in climate change conditions, technologies for breeding animals in difficult weather conditions				•

1. SPSR “Innovative Technologies in the Agroindustrial Complex”, 2011 – 2015
2. SPSR “Chemical Technologies and Materials, Natural and Resource Potential, 2013-2015 (until 2013 - SPSR “Natural Resource Potential” for 2011-2015)
3. SPSR “Fundamentals of biotechnologies”, 2011 – 2015
4. SSTP “Agropromcomplex”

Work related to adaptation of agriculture to climate change was also carried out in 2011-2015 in the framework of a number of other SSTPs and sectoral scientific and technical programs.

In 2016 - 2020 work on breeding and the development of technologies for growing crops with improved characteristics and productivity, resistant to lodging, biotic and abiotic environmental factors, development of resource-saving technologies, structures and methods of calculation for the

[17] The section is prepared based on materials by Mitakovich, 2017.

construction, rehabilitation and maintenance of reclamation systems, development of innovative technologies for reproductive seed farming of vegetable crops using drip irrigation continue within the SSTP "Agropromcomplex 2020 "(subprogram “Agropromcomplex - efficiency and quality"). Continuation of fundamental research and scientific and technical developments in the field of agriculture adaptation is also possible within SPSR "Chemical Technologies and Materials", "Biotechnology", "Quality and Efficiency of Agricultural Production", "Environment and Environmental Management”" and SSTP "Industrial Biotechnology and Nanotechnology - 2020” and “Nature and Environmental Risks".

Measures of adaptation through development of scientific and research activity

- Continuation and implementation of studies in already planned areas (breeding new varieties, reduction of soil degradation, irrigation improvement, protection against pests, weeds and diseases, development of biotechnologies, fodder production, technologies for keeping and breeding animals in the face of climate change);
- Development of fundamental and applied research in new areas recognized in international practice (reduction of emissions of harmful substances in agriculture, integrated application of information technologies, development of "accurate" and integrated agriculture);
- Development of the implementation of outcomes of research, development and technological work (RDTW) through methodological support for transfer and implementation of technologies (operation of technology transfer centers, information and consultancy services), promotion of intellectual creativity and innovative entrepreneurship in the field of agriculture, the use of the State RDTW Registry and other scientific, R&D and innovative information;
- Expansion of the participation of agricultural enterprises as co-executors of RDTW and new product manufacturers under SSTPs and projects financed by the Belarusian Innovation Fund;
- Introduction of the maximum risk level from the volume of financing of scientific and technical programs (which will facilitate the search for performers for RDTW, having a high risk of failure to achieve results, but setting new opportunities for development of the industry);
- Introduction of income tax benefits for scientific organizations similar to the rate for other subjects of innovation infrastructure (which will stimulate scientific, technical and innovative activities on the initiative of organizations employing innovations);
- Study of foreign experience in supporting innovation and knowledge transfer in agriculture through cooperation with specialized centers, organization of "contact-cooperation exchanges", supporting cooperation of small and medium-sized enterprises and scientific organizations with foreign partners, competitions of "innovative vouchers";
- Improving the access of agricultural workers to innovative technologies and information in the field of adaptation to climate change and hydrometeorology.

4.7 Institutional Dimension of Adaptation: Insurance against Risks [18]

Conduct of any entrepreneurial activity occurs against the background of risk and uncertainty. The natural and climatic risk present in agroindustrial production significantly influences the final outcomes of production activities. Annual economic damage to agricultural production from natural disasters is not only comparable with the financial performance of farms, but also periodically exceeds them. In a changing climate, insurance as an effective tool for transferring risks is essential to improve financial sustainability and maintain profitability of agricultural enterprises.

Since 2009, Belarus has compulsory insurance of yields of agricultural crops, livestock and birds. In view of the specifics of agricultural development in the country, compulsory insurance with state support plays a leading role in the industry. The level of development of voluntary insurance of agricultural crops in the country is insignificant because of high tariffs with a small coverage of arising damage by the insurance.

To ensure high-quality insurance protection of agricultural production in a changing climate, it is necessary to improve the legal framework for compulsory agricultural insurance with state participation. At the same time, insurance mechanisms should not only allow the use of insurance reserves in the event of unfavorable climatic events, but also motivate producers to use their land plots and resources efficiently.

With an appropriate combination of compulsory and voluntary forms in the next 5 to 10 years, compulsory agricultural insurance should be a priority, since the participation of all farms in the formation of the insurance fund will support the minimum tariff rates. At the same time, additional voluntary insurance will enable large agricultural enterprises and farms to obtain coverage of their agricultural production in a larger volume and under a wider list of insured risks.

An important direction of improving the insurance system for property of agricultural organizations should be development of new, more sophisticated insurance products, primarily of a complex nature. In particular, the insurance terms need to be supplemented with the principle of compensation for additional (indirect) losses that arise as a result of occurrence of an insured event with respect to a particular type of property, which will allow for more complete insurance protection of agricultural organizations.

The existing insurance practice provides insurance protection only within one year of insurance, not covering the risks associated with the long-term climate change in the country. An important direction can be the development and implementation of a new insurance system that provides insurance of risks associated with the long-term consequences of climate change in agriculture. Introduction of perspective insurance should, first of all, be conducted on the initiative and with the support of the state, with the possibility of transferring such contracts to the category of voluntary insurance in the future.

Measures of adaptation through development and introduction of new insurance options for agricultural risks related to climate change

- Expansion of the list of risks accepted for insurance, as well as reduction of tariffs for insurance of agricultural products against risks associated with the loss or significant decline in the

[18] The section is prepared based on materials by Ye. Malakhovskaya (Minsk branch of the Belarusian Republican Unitary Insurance Company "Belgosstrakh")

productivity of crops, livestock or poultry death or disease due to long-term climate change (shift of agroclimatic zones, increase in the frequency of droughts and arid phenomena, increasing the frequency, duration and intensity of periods of extreme heat ("heat waves"), decreasing number of days with low precipitation or increased precipitation, leading to soil erosion and damage to plants, increasing frequency and duration of winter thaws, and occurrence of new pest species);

- Insurance of losses resulting from non-receipt of profits by the agricultural enterprise as a result of an incorrectly chosen strategy for development and adaptation of the enterprise (for example, in case of unsuccessful attempts to introduce biotechnologies and selection of new agricultural crops, due to the unsuccessful introduction of technologies for increasing yields by using fertilizers and plant protection products, because of structural reorganization of agricultural land and arable land), as well as the need to cover production costs in a situation of no profit;
- Detailed study of the possibility of insurance of financial risks associated with operating expenses (non-repayment of received loans, loans, leasing obligations) in the face of climate change with participation of banks, leasing companies and other interested financial organizations and taking into account the state support of insurance companies;
- Study of the possibilities for "index insurance" with reimbursement of direct costs under index (for example, meteorological) criteria while improving the regulatory framework and practices of its application (including with regard to subsidy mechanisms) by changing tax and insurance legislation, developing and Implementation of elements of additional organizational and financial infrastructure;
- Gradual creation of institutional framework for participation of international insurance companies in reinsurance of risks of agricultural production in the territory of Belarus.

5 MECHANISMS FOR DEVELOPMENT AND INTRODUCTION OF ADAPTATION MEASURES

This Strategy for Adaptation of Agriculture to Climate Change in the Republic of Belarus is prepared within the framework of the European Commission's international technical assistance project and serves only as one of the steps towards a systemic adaptation of this critical industry to future changes in the conditions for production and sale of products. To turn it into a strategic planning tool and into a practical action plan at the junction of agricultural development and public policy on climate change, further steps are required, the key ones of which are described below.

Interdepartmental interaction and participation of other stakeholders

Further actions to develop and, in the future, to implement adaptation measures in agriculture in Belarus will require interaction of key central authorities: the Ministry of Natural Resources and Environmental Protection, which is generally responsible for the development and implementation of state policy on climate change, and the Ministry of Agriculture and Food, responsible for strategic and practical issues of development and the country's agro-industrial complex. In addition to the two abovementioned agencies, other central authorities (including the Ministry of Economy, the Ministry of Forestry, the Ministry of Emergency Situations, the Ministry of Energy, the Ministry of the Energy and the State Property Committee).

Given that a significant part of the adaptation measures will need to be planned for implementation in the context of specific oblasts and regions, it is important to involve relevant territorial units of local authorities, including oblast natural resources and environmental protection committees and the committees on agriculture and food. Consultations with the local authorities should become an integral part of the concrete adaptation measures at the oblast and regional levels, which in the future will require participation of representatives of local authorities.

Large and small agricultural enterprises can provide real assistance both in terms of strategic issues, and in the development, evaluation and testing of specific adaptation measures at the local level. Attraction of agricultural and food business will also help to involve not only the creative potential and influence of the private sector, but also its financial resources, to serve the interests of agricultural adaptation. Finally, organizations of agricultural and related sciences and public organizations, including associations of small producers, are able to support new directions (for example, such as organic farming) and - the latter - in consultations with private farms and the general public, direct work with which is quite often difficult and costly for the government agencies.

Similarly to the working group operating in the field of "organic farming" development, comprising representatives of various organizations, scientific institutions and farmers, it is advisable to consider the possibility of forming an interagency working group first, and then an expanded working group of representatives of interested branches and sectors to systematically discuss adaptation of agriculture to climate change and coordination of preparation and implementation of an action plan for agricultural adaptation.

Such a permanent mechanism can also be used to review and ensure the linkage of adaptation with the issues of integrated development of rural areas, the adaptation of other sectors (in particular, water management and land improvement), as well as for regular review of adaptation priorities, wit account of recent developments, new information and knowledge about climate change and its consequences.

Broader and deeper contents

Full-scale development of an action plan requires a more detailed study of aspects not covered by this Strategy and the Clima East project. First of all, it concerns animal - one of the leading branches of agriculture in Belarus - and fish farming: while the analysis of crop production and plant protection in principle allows us to move to the next level of development and planning of concrete measures for adaptation, so far, only overall trends and directions are envisaged for livestock and fish farming.

Likewise, institutional aspects of agricultural adaptation, which provide the necessary regulatory, legislative, organizational, financial, economic, social and information base, require much more detailed elaboration. From these issues, in the course of preparation of the Strategy, issues of development and promotion of "organic" farming, scientific innovation activities and new mechanisms for insurance of agricultural production risks were considered in detail.

Finally, in the territorial context, the first step was taken to outlining the priorities for the adaptation of Belarusian regions in detail. In the long run, a more detailed territorial analysis of the likely consequences of climate change in terms of specific features of agricultural production in specific areas and further transfer of this analysis to planning practical measures for adapting agriculture to the regional and local levels is needed. It would be instrumental to include the relevant long-term (for example, the development of certain areas of crop production, gardening, etc.) and short-term actions (up to the creation of quick response teams for floods) in adaptation plans to climate change at the level of rural councils (see, for example, International Public Association "Ecoproject", 2016).

Economic analysis and development of activities

The Strategy contains generalized recommendations on selected areas and measures for adapting agriculture to climate change. For their practical implementation, within each of the measures it is necessary to develop specific activities with an assessment of their duration, territorial coverage, implementation mechanisms and required resources (including financial ones). Detailed elaboration of these aspects with a clear distribution of responsibility will allow to start planning and implementing specific activities within the framework of the general action plan.

It would be useful to compare the generalized estimate of the cost of implementation of measures with the expected damage and lost profit in agriculture from climate change in the absence of adaptation, although in global practice the accuracy of such estimates remains insufficient. The calculations performed in the framework of the project (Kozyra et al., 2017) make it possible to make only an enlarged assessment of the possible negative consequences for the Belarusian agriculture in connection with the projected trends of climate change. In particular, if the yield of industrial crops is reduced by 5-20% by 2050, the possible ineffective revenue for the country's agricultural enterprises may amount to 18 - 71 million rubles at current prices. For cereals, the possible economic losses with a decrease in the yield of cereals by 3 - 11%, will amount to 48 - 178 million rubles per year in current prices. It was difficult to perform a detailed assessment of the damage to other crop sectors and livestock in the current project, but it is clear that, in the absence of adequate adaptation measures, the overall negative impact from the effects of climate change can be significant. Executed estimates for a crop failure for only two crops (rape and cereals) already exceed the current direct damage from emergencies and are comparable to the amount of the industry’s gross insurance payments.

Financial and legal framework

Financing of the Action Plan for the implementation of the Strategy for Adaptation of Agriculture to Climate Change in the Republic of Belarus can be implemented at the expense of budgetary funds, funds received from income-generating activities, and other sources permitted by law. A certain role can be played by international mechanisms of technical and financial assistance in the field of adaptation to climate change, the fundamental reform of which is connected with the entry into force in 2016 of the Paris Agreement under the United Nations Framework Convention on Climate Change.

To implement the directions of the Strategy and Action Plan, improvement and further development of the regulatory and legal framework in the field of agricultural production, hydrometeorological activities, environmental protection and use of natural resources will be required. In the future, development of new regulations and introduction of changes and additions to the current legislation should promote introduction of adaptation measures as an integral part of sectoral planning, including creation of mechanisms for "climate analysis" of sectoral projects, plans and programs.

Finally, an important aspect of improving the regulatory framework will be a phased harmonization of agricultural adaptation activities with a reduction in greenhouse gas emissions due to the activities of the agroindustrial complex and the use of the country's land resources.

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